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Extreme population fluctuation in the Northern Pygmy Mouse (*Baiomys taylori*) in southeastern Texas

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Abstract

The Northern Pygmy Mouse (*Baiomys taylori*) occurs throughout much of Mexico and into the southwestern United States, with its range currently expanding northward in the U.S. Despite documentation of species range expansion, there have been very few studies that have monitored population growth patterns in this species. During a 16-month mark-recapture study in coastal southeastern Texas, a striking fluctuation in densities of Pygmy Mouse populations was observed. The extreme population increase and decline was evaluated with respect to several biotic and abiotic variables postulated to affect rodent population levels. Highest population levels were preceded by high fruit and seed availability, and variation in 6-month cumulative precipitation totals explained 73.8% - 77.1% of the population variation in the study.

Key words: *Baiomys taylori;* cumulative precipitation; Northern Pygmy Mouse; population fluctuation; rapid population increase; Texas.

Resumen

El Ratón Pigmeo Norteño (*Baiomys taylori*) se encuentra en gran parte de México y en el suroeste de los Estados Unidos, con su distribución expandiendose hacia el norte en los EE.UU. A pesar de la documentación de su expansión distribucional, ha habido muy pocos estudios que han monitoreado los patrones de crecimiento poblacional en esta especie. Durante un estudio marca-recaptura de 16 meses en la costa sureste de Texas, se observó una fluctuación aguda en las densidades de las poblaciones del ratón pigmeo. El aumento extremo y el descenso posterior de la población fueron evaluados con respecto a algunos cuantas factores bióticos y abióticos postulados a afectar los niveles poblacionales. Los niveles mas altos fueron anticipadas por la disponibilidad alta de frutas y semillas, y la variación de precipitación cumulativa total explicó 73.8% - 77.1% de la variación poblacional en el estudio.

Palabras claves: *Baiomys taylori;* fluctuación poblacional; precipitación cumulativa; Ratón Pigmeo Norteño; subida poblacional rápida; Texas.

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Introduction

The Northern Pygmy Mouse, *Baiomys taylori* (Thomas 1887), is the smallest rodent in North America (adult weight 6 - 9.5 g; Packard 1960, Hudson 1965). This granivorous / herbivorous species occurs in a wide variety of habitats with dense ground cover (Eshelman and Cameron 1987). Its distribution extends from central Mexico northward into the southwestern United States (Packard 1960, Packard 1969, Pitts and Smolen 1989, Choate *et al*. 1990, Stuart and Scott 1992, Tumlison *et al*. 1993, Brant and Dowler 2002).

Because the species' distribution has been expanding northward in recent decades (Choate *et al*. 1990, Brant and Dowler 2002, Green and Wilkins 2010), and such range expansion may hinge upon a population's ability to grow rapidly (Sakai *et al*. 2001), the northern pygmy mouse might be expected to be capable of rapid population growth. Females can conceive as early as 28 days of age and have a gestation period of 20-23 days (Hudson 1974), a mean time between litters of 27.6 days (Blair 1941), and a mean litter size of about 2.5 (range 1-5; Quadagno *et al*. 1970). In a 6-year study in eastern Texas, population densities for *B. taylori* were found to range from 6-84 mice / ha (Grant *et al*. 1985), and other studies have reported density values within this range (Raun and Wilks 1964; Petersen 1975; Gust and Schmidly 1986).

We used a mark-recapture design to monitor population abundance of *B. taylori* as part of a larger study of rodent communities and zoonoses in southeastern Texas (McIntyre *et al*. 2005; Abuzeineh *et al*. 2007; Holsomback *et al*. 2009; McIntyre *et al*. 2009). We discuss biotic and abiotic factors that may have facilitated the dramatic increase and subsequent precipitous decline in population abundance observed during our study.

Methods

This study was conducted at Peach Point Wildlife Management Area (now named Justin Hurst Wildlife Management Area--headquarters at 28º56'58"N, 95º26'18"W) in Brazoria County, Texas, from May 2002 to August 2003. We conducted 6 trapping sessions at approximately 3-month intervals (see Abuzeineh *et al*. 2007 for additional details of sampling). The climate is moderate, with average daily high temperatures of 13°C to 33°C (December and August, respectively), and December and August average lows of 8°C to 24°C , respectively. The area receives an average of 109.2 cm of precipitation per year, much of it (26.7 cm, or 24.4%) in August and September (Table 1).

Two study grids (Fig. 1) were established, each of which was ~1 ha in size. The grids were located ~1 km apart in old-field habitats. Grid One was irregularly shaped, bordered by a marsh, and contained 112 trap stations. Grid Two was rectangular with a narrow pond in the center, and had 101-109 trap stations depending on the water level of the pond during different trapping sessions.

Habitat structure was measured within a 3-m-radius circle centered on each trap location (McIntyre et al. 2009), and each grid was characterized as a composite of these measurements. Plants were identified and percent coverage of 10 mutually exclusive categories (grass, forb, litter [duff], tree, shrub, bare ground, vine, coarse woody debris, water, reed) was measured, following the protocol of Bullock (1996). The availability of potential rodent food sources (fruits and seeds) was assessed during each trapping session by noting which plant species had fruits or seeds present. The availability of seeds was categorized each month as Very Low (<5% of plants with seeds), Low (5-25%), Medium (25-50%), or High (>50%). Fruits were noted as present or not.

Table 1.--Precipitation data (in cm) from Galveston, TX (29.30°N, 94.80°W, ca. 73 km NE of our study site, in a similar coastal location). Data from the KNMI climate explorer, http://climexp.knmi.nl/getprcpall.cgi?someone@somewhere+72242+GALVESTON+, last accessed 15 March 2011. Table also shows 2- to 8-month cumulative precipitation values for each month during our study, including the 6 months during which we sampled. R^2 values are given for comparisons of cumulative precipitation values with estimated abundances of *Baiomys taylori*, for each of the 2 mark-recapture grids. An asterisk after an R^2 value indicates that the regression function (cumulative precipitation as independent variable, abundance as dependent variable) was significant ($0.05 \geq P$). The highest R^2 value for each grid is indicated in bold-face (for both grids, this is the R^2 value for the 6-month cumulative precipitation value).

		Abundances		**Actual and Cumulative Precipitation**							
Year	**Month**	**Grid 1**	**Grid 2**	**Actual**	**2-month**	**3-month**	**4-month**	**5-month**	**6-month**	**7-month**	**8-month**
2001	Oct			11.9							
	Nov			11.1	23.0						
	Dec			6.4	17.5	29.4					
2002	Jan			5.6	12.0	23.1	35.0				
	Feb			1.8	7.4	13.8	24.9	36.8			
	Mar			4.7	6.5	12.1	18.5	29.6	41.5		
	Apr			6.0	10.7	12.5	18.1	24.5	35.6	47.5	
	May	0	0	9.2	15.2	19.9	21.7	27.3	33.7	44.8	56.7
	Jun			13.5	22.7	28.7	33.4	35.2	40.8	47.2	58.3
	Jul			9.5	23.0	32.2	38.2	42.9	44.7	50.3	56.7
	Aug	5	9	37.3	46.8	60.3	69.5	75.5	80.2	82.0	87.6
	Sep			28.9	66.2	75.7	89.2	98.4	104.4	109.1	110.9
	Oct			30.0	58.9	96.2	105.7	119.2	128.4	134.4	139.1
	Nov			7.4	37.4	66.3	103.6	113.1	126.6	135.8	141.8
	Dec	54	233	9.3	16.7	46.7	75.6	112.9	122.4	135.9	145.1
2003	Jan			3.2	12.5	19.9	49.9	78.8	116.1	125.6	139.1
	Feb			4.1	7.3	16.6	24.0	54.0	82.9	120.2	129.7
	Mar	0	5	1.7	5.8	9.0	18.3	25.7	55.7	84.6	121.9
	Apr			2.7	4.4	8.5	11.7	21.0	28.4	58.4	87.3
	May	0	0	2.0	4.7	6.4	10.5	13.7	23.0	30.4	60.4
	Jun			16.9	18.9	21.6	23.3	27.4	30.6	39.9	47.3
	Jul			11.3	28.2	30.2	32.9	34.6	38.7	41.9	51.2
	Aug	0	0	11.7	23.0	39.9	41.9	44.6	46.3	50.4	53.6
R^2 values			**Grid 1**	0.0001	0.0073	0.1883	0.4869	0.7464*	**0.7710***	0.7291*	0.5579
			Grid 2	0.0046	0.0007	0.1487	0.4336	0.6993*	**0.7384***	0.7181*	0.5687

On each grid, Sherman live-traps (7.5 x 9.0 x 23.0 cm) were spaced 10 m apart and baited with rolled oats and peanut butter. Traps were checked each morning and animals processed and released at the point of capture. Traps were opened and rebaited in late afternoon. The populations were sampled for 6 nights each trap session, except August and December 2002 (4 and 5 nights, respectively). Captured rodents were marked with a unique identification number using toe-clipping during the first sampling session period Following IACUC recommendations, passive integrated transponder (PIT) tagging was used in all subsequent sessions. Additionally, age (adult, subadult, or juvenile; determined by examining pelage and weight), sex, and trap station were recorded. Field protocols followed accepted guidelines (Animal Care and Use Committee, 1998) and were approved by the Texas Tech University Animal Care and Use Committee.

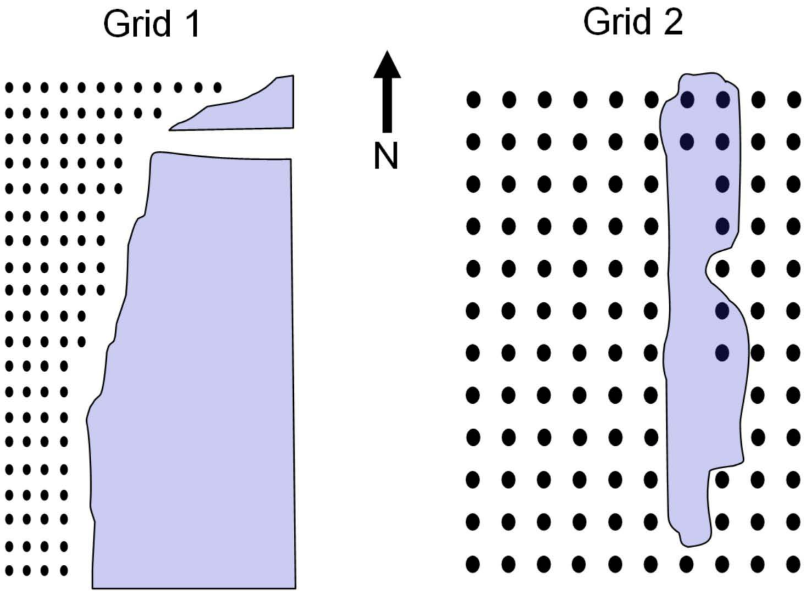

Figure. 1—Illustration of the 2 study grids, not drawn to same scale (traps are spaced 10m apart in both directions, in both grids). Trap stations are denoted with black ovals. Shaded areas represent bodies of water. Note that on Grid Two, some trap stations were located in areas that were inundated during some trapping sessions.

The software program MARK (White and Burnham 1999;) was used to estimate population abundances. The program assumes a closed population during a given trapping session. We used the Pollock and Otto (1983) model (M_{bh}), which estimates population sizes based on new and recaptured individuals, allowing both for different probabilities of capture between first capture and recaptures and inter-individual heterogeneity of capture (or recapture) probability. This and similar algorithms, based on temporal patterns of capture and recapture of individual rodents within closed populations, produce accurate estimates of population size, particularly with high numbers of captures and recaptures (Otis et al. 1978; White and Burnham 1999; Owen et al. 2010). However, when trapping success is relatively low (i.e., $\leq$ 10 individuals encountered), these and similar algorithms generally cannot produce reliable estimates; in these cases, the Minimum Number Known Alive (MNKA; i.e., the number of individuals actually encountered) method was used to estimate population size.

Monthly precipitation data were obtained from the KNMI climate explorer, from Galveston, TX (29.30°N, 94.80°W, ca. 73 km NE of our study site, in a similar coastal location), http://climexp.knmi.nl/getprcpall.cgi?someone@somewhere+72242+GALVESTON+. For each of our six sampling periods, cumulative precipitation was calculated for the preceding two through eight months (Table 1). R^2 values were calculated between each of these series of cumulative precipitation values and the estimated *Baiomys* population abundances, for both grids. R^2 values and associated *P* values were calculated using SAS ver. 9.2 (SAS Institute, Inc., Cary, NC).

Results

Both of the mark-recapture grids were dominated by grass and forb cover with few trees, but the two grids differed in terms of vegetative composition (Table 2). Grid One supported 31 - 34 species of plants, depending upon the season, and overall was dominated by bluestem (*Andropogon* sp.) and baccharis (*Baccharis halimifolia*). Grid Two supported 31 – 37 plant species and was composed primarily of balloonvine (*Cardiospermum halicacabum*), elderberry (*Sambucus canadensis*), and flatsedge (*Cyperus* sp.). More detailed vegetative descriptions may be found in McIntyre *et al*. (2005, 2009).

Table 2—Habitat composition for each mark-recapture grid by month and year, with number of plant species present and percent ground cover within 3 m of each trap, averaged over all traps per grid for a given time period (G = grass, F = forb, L = litter [duff], T = tree, S = shrub, others = other cover types pooled [bare ground, vine, coarse woody debris, water, and reed]).

Grid One

Month	Year	# plant species	%G	%F	%L	%T	%S	%others
May	2002	34	63.75	17.26	0.31	2.06	1.79	14.83
Aug	2002	33	59.05	18.95	0.31	1.67	1.65	18.37
Dec	2002	31	59.54	18.75	0.31	1.87	1.67	17.86
Mar	2003	32	60.07	18.73	0.32	1.87	1.68	17.33
May	2003	33	57.29	20.98	0.31	1.90	1.63	17.89
Aug	2003	34	52.00	18.96	0.31	1.90	1.65	25.18

Grid Two

Month	Year	# plant species	%G	%F	%L	%T	%S	%others
May	2002	34	58.77	16.05	0.05	6.20	0.16	18.77
Aug	2002	37	55.24	23.32	0.05	1.47	0.11	19.81
Dec	2002	31	49.25	29.06	0.05	1.70	0.13	19.81
Mar	2003	31	49.61	28.86	0.05	1.69	0.13	19.66
May	2003	34	47.82	29.27	0.05	2.17	0.13	20.56
Aug	2003	34	43.00	25.00	0.05	1.50	0.11	30.34

During August-October 2002, the area received considerably higher than average rainfall, after which precipitation levels returned to normal or lower than normal (Table 1). During these 3 months, total rainfall was 96.2 cm, or 269% of the average 3-month total of 35.7 cm.

May 2002 and 2003 demonstrated very low seed abundance, whereas August 2002 and 2003 showed very high seed abundance (especially among the grasses) as well as the presence of fruits (e.g., elderberry and various other shrubs, forbs, trees, and vines). December 2002 and March 2003 showed medium and low seed abundances, respectively (Fig. 2). These patterns corresponded to seasonal changes in plant phenology.

During our study, 110 *Baiomys taylori* were captured, with more individuals encountered on Grid Two than on Grid One. Grid One yielded no *B. taylori* during 4 of 6 trapping sessions (May 2002 and March, May, and August 2003), 5 individuals (3 adult females, 2 adult males) in August 2002, and 30 (12 adult females, 6 adult males, 12 subadults) in December 2002. Grid Two yielded no *B. taylori* during 3 of 6 trapping sessions (May 2002 and May and August 2003), 9 individuals (6 adult females, 3 adult males) in August 2002, 61 (24 adult females, 26 adult males, 11 subadults) in December

2002, and 5 (2 adult males, 3 subadults) in March 2003 (Fig. 2*)*. In December 2002, population abundances were estimated at 54 ± 15.9 (±SE) on Grid One and 233 ± 119.2 (±SE) on Grid Two. For all other sampling sessions, the MNKA (number of animals encountered) was used as the best estimate of the population size.

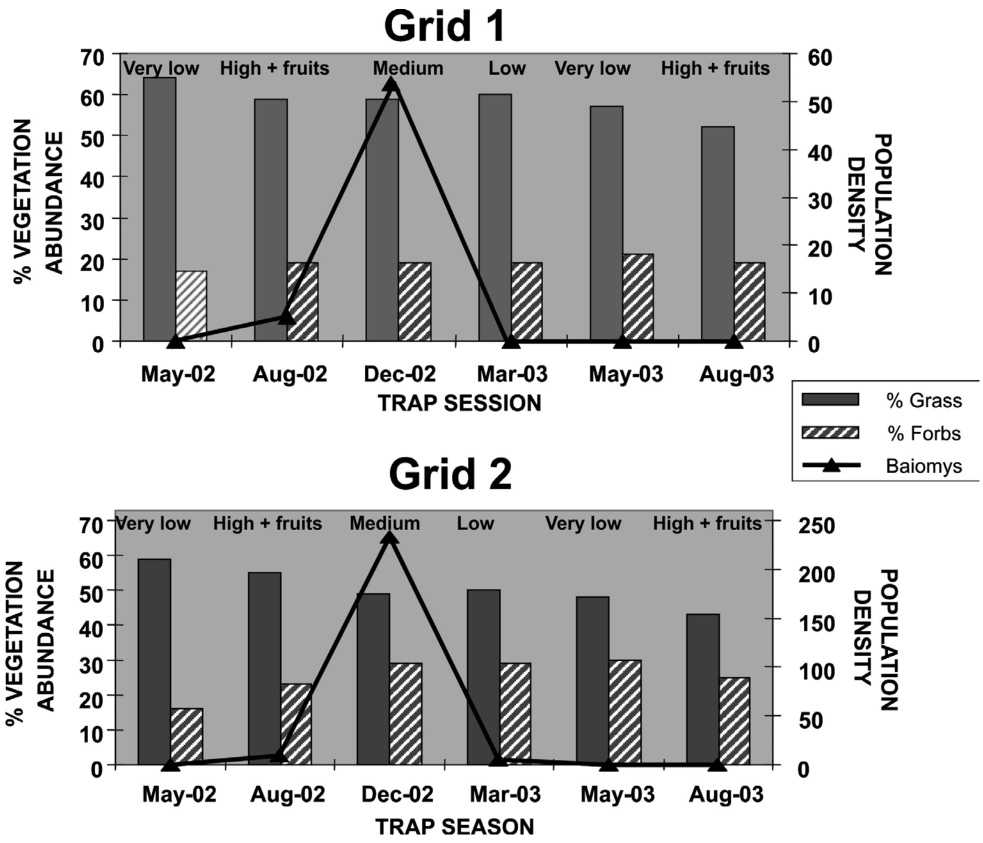

Figure. **2** Population abundance estimates for *B. taylori* (solid lines, right-hand Y axis), vegetation composition (grasses in gray bars, forbs in striped bars, left-hand Y axis), and seed abundance and fruit presence of grids 1 and 2 during 6 trapping sessions. Quantitative assessments of seed abundances are shown at the top of each graph, as Very Low (<5% of plants with seeds), Low (5-25%), Medium (25-50%), or High (>50%), with fruits noted when present. Note the difference in scale between the two grids for the right-hand Y axis.

R^2 values provided a measure of the proportion of the variance in population values which is explained by the cumulative precipitation levels for 2- to 8-month periods (Table 1). R^2 values were significant ($\alpha = 0.05$) for both grids for the 5-, 6-, and 7-month cumulative precipitation values, and highest for 6-month levels ($R^2 = 0.7710$ for grid 1 and $R^2 = 0.7384$ for grid 2; Table 1).

Discussion

On both grids, *Baiomys* were not encountered in May 2002, were recorded in small numbers in August, then experienced a dramatic population increase by December, followed by a precipitous decline in 2003. These trends were noted on both of our mark-recapture grids. Animals marked on one grid were not captured at the other, nor were grid-marked animals caught on any of several ancillary trap lines that were placed in similar habitats (at least 100 m from the mark-recapture grids). Although the results from ancillary trap lines cannot be used to estimate population abundance, capture rates on these lines closely paralleled those on the mark-recapture grids. We therefore are confident that our population estimates were representative and that the trends we saw were general for the area, and not idiosyncratic to a particular grid or habitat type.

Relatively constant forb and grass compositions in the study area appear to provide a favorable environment year-round for breeding individuals. Additionally, we noted that high population abundance occurred in sampling sessions following high seed abundances and presence of fruits. Our vegetation data indicate that these fluctuations correspond well with seasonal changes in food availability. Small mammals consuming low-caloric foods (e.g., grasses and seeds) have greater energy constraints per unit mass relative to resting metabolic rates than do small mammals that utilize high-energy resources. Because there are varying benefits and costs associated with different food resources, a relationship between rodent diet and reproductive behaviors has been hypothesized (Kalcounis-Rüppell and Ribble 2007).

However, the vegetation data do not explain well why abundances were considerably lower (5 and 0 individuals in March 2003 on Grids One and Two, respectively) in seasons subsequent to the population increase. The decline is especially puzzling given that most subadult animals were encountered in December 2002, with a few also in March 2003, indicating that breeding was continuing during this period. Moreover, no subadult animals were encountered in August 2002, suggesting that the extreme population increase actually began after that trapping session, and therefore occurred in less than 4 months.

Although we cannot demonstrate a direct causal link between precipitation and population trends, we note a strong and consistent pattern in which a significant proportion of the variation in population levels is explained by the cumulative precipitation preceding each of our sampling sessions. The R^2 levels increased steadily to peak at 6-month cumulative values, then declined to 8-month (and presumably greater) levels.

The capacity of *Baiomys taylori* for early and rapid reproduction (Blair 1941, Quadagno et al. 1970, Hudson 1974) certainly contributed to the rapid increase in abundance for the species. As with any species, the historical range of *B. taylori* undoubtedly results both from the interaction of biotic and abiotic components of its environment, and species-specific life history traits, such as age at first reproduction and litter size. Further, population "pulses" such as that documented in this study, not only may be contributing to the current range expansion of *B. taylori*, but also may have higher-order effects within the trophic system of which it plays an integral role. Therefore, these dynamics are worthy of future evaluation in this and other small mammal populations, particularly across areas where climate patterns are highly variable, or are documented to be changing.

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