DEMOGRAPHIC FEATURES AND HABITAT PREFERENCES OF *OSGOODOMYS BANDERANUS* (OSGOOD'S DEERMOUSE) IN COLIMA, MEXICO

CASSIE J. POINDEXTER, GARY D. SCHNELL,* CORNELIO SÁNCHEZ-HERNÁNDEZ, MARÍA DE LOURDES ROMERO-ALMARAZ, MICHAEL L. KENNEDY, TROY L. BEST, MICHAEL C. WOOTEN, AND JULIANN L. WAITS

Sam Noble Oklahoma Museum of Natural History and Department of Biology, University of Oklahoma, 2401 Chautauqua Avenue, Norman, OK 73072 (CJP, GDS)
Departamento de Zoología, Instituto de Biología, Universidad Nacional Autónoma de México, Apartado Postal 70–153, Coyoacán, México, Distrito Federal 04510, México (CS-H)
Escuinapa No. 92 bis. Colonia Pedregal de Santo Domingo, C.P. 04360, México, Distrito Federal, México (MLR-A)
Ecological Research Center, Department of Biological Sciences, University of Memphis, Memphis, TN 38152 (MLK, JLW)
Department of Biological Sciences, 331 Funchess Hall, Auburn University, AL 36849 (TLB, MCW)
**Correspondent: gschnell@ou.edu*

ABSTRACT—*Osgoodomys banderanus* (Osgood's deermouse) was studied in January 2006 and 2007 in north-central Colima, Mexico. During 8 nights each year, five mark-recapture grids were established with elevated and ground traps. For 16,000 trap-nights, 123 individuals were captured 385 times (comprising 9.4% of captures on grids); one-third of captures were in elevated traps. The ratio of males to females was 1.51:1 (significantly different from 1:1). No sexual dimorphism in mass was detected, 84.4% were adults, and 41.5% of adult females were pregnant or lactating. Average distance between successive captures was 19.62 m, and average distance from a central point of capture was 12.74 m. *Osgoodomys banderanus* was captured on 6 of 10 grids (densities 0.76–30.55 individuals/ha). Probability of capture or recapture was influenced by trapping night, with probabilities peaking on nights 6 and 7. Habitat preferences were based on 14 environmental variables taken at each trapping station. Logistic regression indicated *O. banderanus* preferred higher canopies, closer trees, more rocks, and less grass; a model developed with nonparametric multiplicative regression consisted of the first three of these variables. *Osgoodomys banderanus* exhibited strong preferences for rocky areas with less dense ground cover, a more open understory, and a tall canopy.

RESUMEN—*Osgoodomys banderanus* (ratón de Osgood) fue estudiado en enero de 2006 y 2007 en la zona centro-norte de Colima, México, durante ocho noches por cada año en un estudio de captura y recaptura en cuadrantes. Cada año se establecieron cinco cuadrantes con trampas arbóreas y sobre el suelo. Para 16,000 trampas-noches, 123 individuos fueron capturados 385 veces (que corresponde a 9.4% de las capturas en los cuadrantes) y una tercera parte de las capturas fueron en trampas arbóreas. La proporción macho-hembra fue 1.51:1 (significativamente diferente de 1:1). No se encontró dimorfismo sexual en peso, 84.4% fueron adultos, y 41.5% de las hembras adultas estaban preñadas o lactando. La distancia promedio entre capturas sucesivas fue de 19.62 m, y la distancia promedio desde un punto central de captura fue de 12.74 m. *Osgoodomys banderanus* fue capturado en 6 de 10 cuadrantes con densidades de 0.76–30.55 individuos/ha. La probabilidad de captura o recaptura fue influenciada por trampa-noche, con la mayor probabilidad entre la 6a. y 7a. noche. Preferencias de hábitat se evaluaron usando medidas de 14 variables ambientales registradas en cada estación de trampeo. Regresión logística indicó que sitios frecuentados por *O. banderanus* tuvieron el dosel más alto, árboles más cercanos, más rocas y menos pastos; un modelo desarrollado con regresión multiplicativa no paramétrica consistió de las tres primeras variables. *Osgoodomys banderanus* mostró una fuerte preferencia por áreas rocosas con menor densidad en la cobertura del suelo y con un sotobosque más abierto y dosel alto.

Osgoodomys banderanus (Osgood's deermouse) is a nocturnal, solitary, medium-sized cricetid that is endemic to western Mexico, in particular the western portion of the Trans-Mexican Neovolcanic Belt (Fa and Morales, 1991). The species occurs throughout the state of Colima (Ceballos and Miranda, 2000; Fig. 1; Appendix lists localities). Its distribution is limited along the coastal plain from southern Nayarit to southern Guerrero and

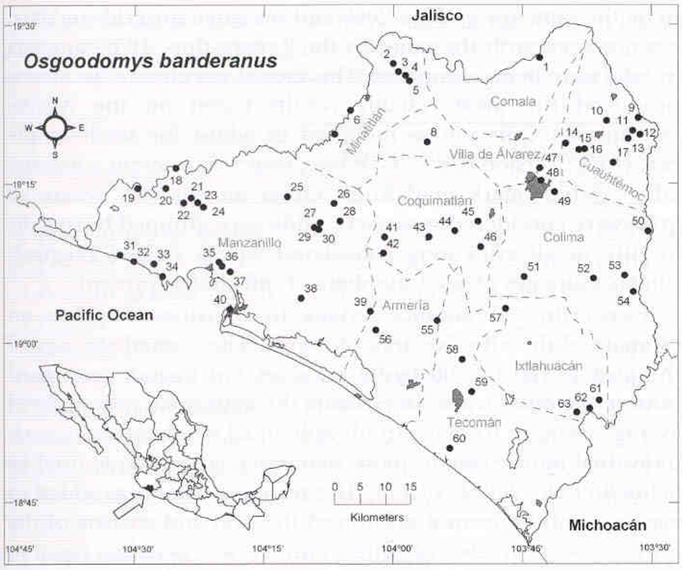

Fig. 1—Localities in Colima, Mexico, where Osgood's deermouse *Osgoodomys banderanus* has been captured (see Appendix for gazetteer). Grids 1 and 2 in 2006 were at locality 14, while grids 3 and 5 in 2006 and all five grids in 2007 were at locality 17. Bodies of water are shown (outlined), as are some cities and towns (shaded). Dashed lines indicate geographic boundaries of 10 municipalities in the state that are named after the principal city or town in each.

into the interior of Michoacán and Guerrero along the basin of the Río Balsas, Mexico (Musser and Carleton, 2005). The range of *O. banderanus* is extensive (230,000 km^2), and the species is not considered to be of particular conservation concern (Glazier, 1980), but it occurs primarily in Pacific tropical to subtropical dry forest, an area that increasingly is being subjected to habitat degradation and widespread clearing (Sánchez-Azofeifa et al., 2005). In addition, *O. banderanus* occurs in hotspots for biodiversity and endemism, as well as in regions considered a priority for conservation of nonvolant mammals (Ceballos and Navarro L., 1991; Fa and Morales, 1991; Arita et al., 1997).

Relatively little is known about the basic ecology and demography of *O. banderanus*, a condition fostered in part by its varied taxonomic treatment. There has been debate over several decades concerning placement of the species within the subfamily Neotominae. Originally assigned in the genus *Peromyscus*, Carleton (1980), in a morphological study, was the first to advocate that the species be classified in its own genus, a recommendation followed by Musser and Carleton (2005).

The ecology and habitat use of *O. banderanus* has been described only in general terms, mostly in brief field remarks, with only a few studies reporting on specific demographic parameters. The primary work on the species has been by Ceballos Gonzalez (1989) as part of his study of small mammals of deciduous and semi-deciduous forests at the Chamela Biological Station in Jalisco.

Given the relative paucity of information on demographic features and ecology of *O. banderanus*, mark-recapture studies were conducted with the specific objectives to describe habitat preferences of *O. banderanus*, as well as to report sex ratio, reproductive status, age structure, and population density. Additional objectives were to acquire information on use of understory, probability of capture, and movements of males and females.

Materials and Methods—*Study Area and Trapping*—This study was conducted at Rancho La Angostura, Colima (locality 14, Fig. 1) in 2006 and sites in the vicinity of the Miguel de la Madrid Airport (locality 17) in 2006 and 2007. Five trapping grids were established each year (10 total) during the annual dry season in January. Days were warm and nights were cool (January average during 1961–2005 for Manzanillo was 24.6°C; Instituto Nacional de Estadística, Geografía e Informática, 2006), with little day-to-day variation in temperature and no rain. Grids were placed to include the major types of vegetation present. Each grid consisted of 100 trapping stations (10 by 10 square grid), with stations 10 m apart. Two Sherman live traps (7.5 by 9.0 by 23.0 cm) baited with rolled oats were placed at each station, one on the ground and one elevated 1–2 m above ground on a thin plywood platform (12.5 by 34.5 cm) attached to a tree or shrub. Grids were sampled for 8 nights each; thus, overall sampling effort on the grids involved 16,000 trap-nights.

Grids 1–2 in 2006 at Rancho La Angostura (sampled 2–6, 10–12 January) were 700–765 m in elevation, and vegetation on grids was tropical deciduous forest (bordered by a small stream) in an overall landscape that was fragmented due to cultivated agriculture (mainly oranges and limes) and raising of livestock. However, the area containing the grids had native vegetation (some *Ficus* trees ≤5 m in circumference) with heavily shaded gallery forest (trees 5–40 m in height). Numerous species of trees were present, the most abundant being *Alnus*, *Salix humboldtiana*, *S. bonplandiana*, *Cecropia obtusifolia*, *Ficus*, and *Inga eriocarpa* (Schnell et al., 2008*b*). Cultivated coffee trees (*Coffea arabica*) were in the understory on both grids at this location.

The second locality, adjacent to the Miguel de la Madrid Airport, included grids 3–5 in 2006 (sampled 3–6, 10–13 January) and all five grids in 2007 (grids 1–3 sampled 2–6, 10–12 January and grids 4–5 sampled 3–6, 10–13 January). None of the grids overlapped within or between years. The study area had been fragmented and used for agriculture in the past but was protected and relatively undisturbed for 30 years prior to our study. Much of the area studied had reverted to tropical moist forest intermixed with grass-dominated habitat (*Andropogon*, often >2 m tall). Characteristic trees were *Brosimum alicastrum*, *Sideroxylon cartilagineum*, *Coussapoa purpusii*, *Hura polyandra*, *Guarea glabra*, *Dendropanax arboreus*, and *Populus guzmanantlensis* (Schnell et al., 2008*b*).

Grids 3–5 in 2006 were predominately thorn forest. Grid 4 had patches of tall grass associated with small stream and riparian habitat of dense vines and large deciduous trees. Grids 3 and 5 had sparse understory vegetation intermixed with patches of tall grass (1.0–1.5 m). In 2007, grids 1 and 2 had tropical deciduous forest with mature trees and thorn-forest elements, with grid 1 featuring a sparse understory and a partially cleared, unimproved road traversing the grid. Grids 3 and 4 had dense thorn forest with vines creating low, thick canopy cover, while some areas had mature deciduous trees and patches of tall grass in open areas. Grid 5 featured tall dense grass (1.0–3.0 m) with isolated trees.

Traps were checked once each day starting at dawn, rebaited if needed, and opened for the full 24-h period. For each *O. banderanus* captured, we recorded position of trap (i.e., trapping station on the grid and ground versus elevated), gender, reproductive status (based on external condition of reproductive organs), and age (adult, subadult, or juvenile based on size, mass, and pelage coloration). Typically, animals were tagged in both ears using uniquely numbered Monel No. 1 ear tags (National Band and Tag Company, Newport, Kentucky) to ensure that individuals could be identified throughout the course of study. Mice were released at site of capture.

Taxonomy follows Musser and Carleton (2005), except *Liomys* is treated as being part of *Heteromys* as proposed by Hafner et al. (2007). Secondary verifications of identity of species were made by comparison of mitochondrial DNA sequences. Sequence patterns from a region 680 nucleotides long of the cytochrome *b* gene were generated from tissue samples collected at the time of original capture (data not shown). Sequences were compared visually to multiple sequences available in the GENBANK repository (Benson et al., 2009) representing known cytochrome *b* sequences from *Osgoodomys*. Because of the close morphological association between *Osgoodomys* and *Peromyscus*, comparisons also were made to multiple species of *Peromyscus* (*P. aztecus*, *P. hylocetes*, *P. spicilegus*) reported to be present in the state of Colima. Similarity between nucleotide sequences of the field-collected specimens and GENBANK sequences of *Osgoodomys* were all >99%.

Estimation of Movement, Probability of Capture, Abundance, and Density—For each *O. banderanus* captured more than once, we calculated the centroid of capture sites. Distance from centroid was calculated for each trapping location and the mean determined for each individual. This measure of movement has been used previously for *Baiomys musculus* and *Sigmodon mascotensis* (Schnell et al., 2008*b*, 2010*b*). Movement also was assessed by determining average distance between successive captures (Slade and Swihart, 1983), which was calculated weighting each occurrence equally (e.g., an individual caught five times would contribute four data points while one caught two times would provide one).

The computer program MARK (Version 6.0; G. C. White, http://warnercnr.colostate.edu/~gwhite/mark/mark.htm) was used to estimate abundance (i.e., population size) of *O. banderanus* and to estimate probability of capture on a given trapping night. Assuming a closed population during the trapping period, the program compared relative proportions of marked and unmarked animals in successive samples to estimate abundance. We used the Huggins closed-captures option (Huggins, 1989, 1991), in which the two parameters estimated were p, the probability of capture, and c, the probability of recapture; these in turn were involved in deriving N, the abundance for a given grid. Parameters p and c were considered equal in our model but could vary with time (t; i.e., the 8 trapping nights were estimated independently of one another); this model is indicated by $p(t) = c(t)$. Probabilities of capture and recapture for the 8 trapping nights were considered to be the same for grids in 2006 and the same for grids in 2007, but not necessarily the same for the 2 years; thus, 16 parameters in total were being estimated. This model was chosen because it produced the most reliable results based on the Akaike Information Criterion as modified to adjust for small-sample bias (AIC_c; Version 6.0; G. C. White, http://warnercnr.colostate.edu/~gwhite/mark/mark.htm). Other models (i.e., where all grids were considered separately, grids were grouped by specific locality, or all grids were considered equal) yielded relatively similar estimates of total numbers of individuals present.

Converting abundance values to densities requires an estimate of the effective area of a grid. The immediate area of the grid (8,100 m^2; 90 by 90 m) does not include area used outside the outer traps. To estimate the edge area, we employed average distance from centroid, with equal weight given to each individual mouse caught more than once, a technique used by Schnell et al. (2008*b*, 2010*b*). The resulting value was added to each side of the central portion of the grid and corners of the grid area were treated as being rounded with a radius equal to average distance from centroid. Using distance from centroid as reported in Results, the effective area of a grid was estimated to be 1.320 ha.

We also analyzed probability of capture relative to moonlight. Information on the fraction of the moon illuminated for each trapping night was obtained from the United States Naval Observatory (http://www.usno.navy.mil/USNO/astronomical-applications/data-services/frac-moon-ill).

Structure of Vegetation—Following Schnell et al. (2008*a*, 2008*b*), we quantified environmental variation by evaluating 14 characteristics, most of which reflected structure of vegetation (Table 1). Measurements were made at points 1 m from each trapping station (1,000 points total). Percentage of ground cover was estimated (to nearest 5%) for a 1-m square (first seven variables in Table 1). Number of vegetation stems hitting a 1-m bar at 1-m height was determined four times (once in each cardinal direction from central point) and the average calculated (variable 8). Canopy cover (i.e., percent closed, variable 9) was estimated with a spherical densitometer (model C; Forest Densitometers, Bartlesville, Oklahoma), as was slope (variable 10) with a clinometer. Using a 7.5-m vertical pole marked at each decimeter, we recorded the number of decimeter intervals within which vegetation touched the pole; data were totaled for 0–2.5 m (maximum of 25 hits; variable 11) and for 2.5–7.5 m (maximum of 50 hits; variable 12). Maximum height of canopy was estimated to the nearest 0.5 m (variable 13). Distance to nearest tree ($\geq$10 cm dbh; diameter at breast height) was determined in each of four quadrants (with edges being the cardinal directions) and the average taken (variable 14); distances $\geq$10 m were tabulated as 10 m.

Habitat Analyses—For each grid, we obtained the mean and *SD* of the 14 environmental variables, comparing these 28 measurements (means and *SD*s) for grids where *O. banderanus* was present with those for grids where it was not detected. Parallel analyses involved the contrast of means and *SD*s of environmental variables for trapping stations where the species was captured and not captured.

Stepwise logistic regression (SYSTAT Software, Inc., 2007) was used to examine the relationship between environmental measures at trapping stations where *O. banderanus* was captured and not captured. The dependent variable was logit (Y), which is the natural logarithm of the odds of the species being present,

TABLE 1—Mean ± *SD* of 14 environmental variables on trapping grids, contrasting stations where Osgood's deermouse *Osgoodomys banderanus* was captured and not captured in Colima, Mexico.[a]

Variable	2006 Captured ($n = 97$)	2006 Not captured ($n = 403$)	2007 Captured ($n = 65$)	2007 Not captured ($n = 435$)	2006–2007 Captured ($n = 162$)	2006–2007 Not captured ($n = 838$)
1 Percent woody plants	9.5 ±8.39	8.6 ± 12.73	2.8 ± 6.19	2.9 ± 5.48	6.9 ± 8.24	5.6 ± 10.07
2 Percent forbs	7.7 ± 5.30	7.6 ± 11.65	6.4 ± 4.55	7.7 ± 12.50	7.2 ± 5.04	7.6 ± 12.09
3 Percent grasses	2.9 ± 14.17***	29.3 ± 35.57	4.0 ± 6.51***	31.7 ± 33.65	3.4 ± 11.70***	30.5 ± 34.58
4 Percent litter	36.0 ± 15.83***	25.8 ± 21.67	58.5 ± 17.54***	41.0 ± 28.78	45.0 ± 19.83***	33.7 ± 26.69
5 Percent dead wood	17.2 ± 9.13***	9.3 ± 10.41	7.5 ± 11.32	5.9 ± 8.45	13.3 ± 11.11***	7.5 ± 9.60
6 Percent rocks	15.6 ± 15.73***	9.7 ± 13.44	20.0 ± 14.60 ***	5.1 ± 9.52	17.3 ± 15.40 ***	7.3 ± 11.79
7 Percent bare ground	11.0 ± 10.23	9.7 ± 11.25	0.8 ± 2.43 ***	5.8 ± 8.60	6.9 ± 9.48	7.7 ± 10.14
8 Average hits at 1 m	1.67 ± 2.981 ***	4.90 ± 6.754	1.37 ± 1.340 ***	5.16 ± 7.287	1.55 ± 2.457 ***	5.03 ± 7.033
9 Percent canopy closed	81.0 ± 19.44 ***	67.2 ± 33.88	89.5 ± 7.74 ***	46.9 ± 33.29	84.4 ± 16.33 ***	56.7 ± 35.06
10 Slope (degrees)	17.0 ± 9.11 ***	11.0 ± 10.84	5.4 ± 3.86 ***	4.2 ± 2.86	12.3 ± 9.37 ***	7.5 ± 8.50
11 Total hits low	4.97 ± 4.485 ***	7.60 ± 5.026	5.03 ± 2.947 ***	6.54 ± 4.319	4.99 ± 3.930 ***	7.05 ± 4.699
12 Total hits high	6.72 ± 9.273 ***	4.36 ± 7.746	4.80 ± 3.256 ***	2.01 ± 2.781	5.95 ± 7.509 ***	3.14 ± 5.849
13 Maximum canopy height (m)	20.9 ± 11.41 ***	10.3 ± 9.80	10.4 ± 3.14 ***	4.9 ± 3.00	16.7 ± 10.40 ***	7.5 ± 7.63
14 Average distance to nearest tree (m)	2.4 ± 1.58 ***	4.7 ± 2.65	2.4 ± 1.20 ***	5.8 ± 3.04	2.4 ± 1.44 ***	5.3 ± 2.91

[a] Asterisks indicate statistical differences (one-way ANOVA): *, $P \leq 0.05$; **, $P \leq 0.01$; ***, $P \leq 0.001$; no symbol, $P > 0.05$.

and 14 environmental measures were used as potential independent variables. A variable was entered into the equation if $\alpha < 0.05$; after adjustment of the equation taking into account the additional variable, a variable was removed if $\alpha > 0.045$. McFadden's ρ^2-statistic (range, 0–1) was used to evaluate resulting models as a whole.

Nonparametric multiplicative regression (program HyperNiche; McCune and Mefford, 2009) also was used to model habitat preferences based on the 14 environmental variables. Nonparametric multiplicative regression effectively represents response of a species to multiple habitat factors, factor interactions are automatically accommodated for, and overall form of the response surface need not be specified in advance (B. McCune, http://www.pcord.com/NPMRintro.pdf). The technique has been used in analysis of habitat preference of other small mammals, including *Nyctomys sumichrasti* and *Sigmodon mascotensis* (Schnell et al., 2010*a*, 2010*b*).

We employed the local-mean model type, where weighting around each target point was based on a Gaussian (humpbacked) function. In local-mean models, tolerance (i.e., *SD* of a Gaussian weighting function) is related inversely to importance of variables in models (B. McCune, http://www.pcord.com/NPMRintro.pdf). To select the best overall model, we used Log *B* as a measure of fit.

Other Statistical Analyses and Software—SigmaPlot 11 (Systat Software, Inc., 2008) was used to conduct linear- and multiple-regression analyses. BIOMstat for Windows 3.3s (Rohlf and Slice, 1999) was used in univariate analyses, including R×C contingency, goodness-of-fit, and Fisher's exact tests for analysis of frequencies, and linear regression, and analysis of variance (ANOVA) to assess continuous variables.

RESULTS—*Trapping*—*Osgoodomys banderanus* was caught on 6 of 10 grids, with 1–40 individuals on a grid (Table 2), for a total of 123 individuals and 385 captures. On average, we caught males 2.9 ± 1.7 (*SD*) times and females 3.5 ± 2.1 times, with an overall average of 3.1 ± 1.9 captures/individual for the 8-night trapping sessions. We recaptured 69.9% of individuals, with no difference for sex or year (Fisher's exact tests; $P = 1.000$ and 0.156, respectively). However, there was a significant difference for age, with 75.7% of adults being recaptured in contrast to 42.1% of juveniles or subadults (Fisher's exact test, $P = 0.006$).

One-third of all captures were in elevated traps (128 of 385; 33.2%) with a range of 27.3–42.4% on individual

TABLE 2—Total number of individuals captured and estimates of density for Osgood's deermouse *Osgoodomys banderanus* on individual grids where the species was trapped in Colima, Mexico. Size of population (*N*) was estimated using MARK based on model $p(t) = c(t)$. Probabilities of capture (p) and recapture (c) were considered equal for a given night (t) and could vary among nights but were the same for all grids in 2006 and the same for all grids in 2007.

Year and grid	Number captured	$N \pm SE$ (95% confidence interval)	Density (animals/ha)
2006			
1	33	33.90 ± 0.992 (33.16–38.17)	25.69
2	28	28.76 ± 0.910 (28.12–32.82)	21.80
4	16	16.44 ± 0.680 (16.05–19.84)	12.46
2007			
1	40	40.31 ± 0.579 (40.03–43.41)	30.55
3	1	1.00[a]	0.76
4	5	5.04 ± 0.200 (5.00–6.38)	3.82

[a] With only one individual caught, program MARK was unable to provide a robust estimate of density.

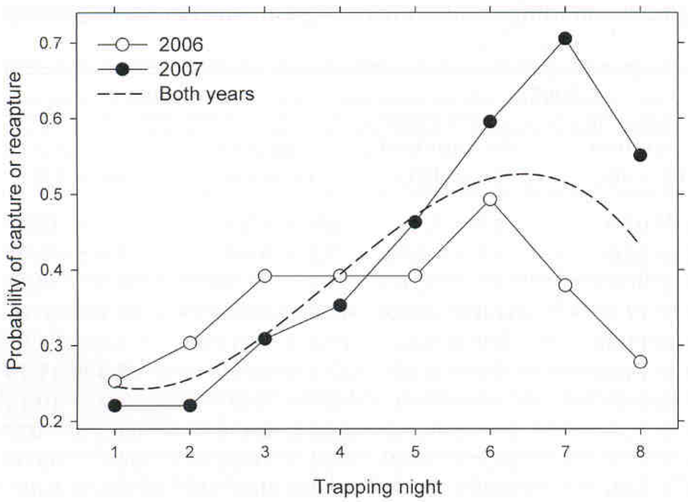

FIG. 2—Estimates of probability of capture or recapture for individual Osgood's deermice *Osgoodomys banderanus* on a given trapping night. Equation for a nonlinear regression line based on data from both years was $Y = 0.310 - 0.109X + 0.049X^2 - 0.004X^3$, where Y is the probability of capturing an individual and X is the trapping night on any given grid.

grids, but no significant difference was detected among grids (R×C test, $G_4 = 5.62$, $P = 0.229$). Of individuals captured more than once (86 individuals), 68.6% were captured in both elevated and ground traps, 25.6% only in ground traps, and 5.8% only in elevated traps.

Probability of Capture Relative to Trapping Night and Moonlight—For trapping nights, we tabulated the proportion of the moon illuminated, which during our study was 0.07–1.00. Lunar illumination, when considered alone or in combination with trapping night, statistically did not explain the probability of capturing *O. banderanus*. However, based on data for both years, a nonlinear regression (Fig. 2) was highly significant for trapping night, with an increase in probability of capture from nights 1–6 with a gradual decline thereafter ($F_{3,12} = 5.81$, $P = 0.011$, $R^2 = 0.592$). A similar pattern emerged when analyzing years separately. For both years, the first trapping night had the lowest capture probability (<0.3) and trapping probability tended to increase with successive nights until it peaked and decreased on night 6 or 7 (Fig. 2).

Demographic Characteristics—In both years, adult *O. banderanus* were captured more frequently than subadults or juveniles: 2006, 81.6% adults (62 adults of 76); 2007, 89.1% adults (41 of 46); and both years, 84.4% adults (103 of 122). No significant difference between years was detected (Fisher's exact test, $P = 0.312$).

We captured more adult males than adult females: 2006, 56.5% males (35 males and 27 females); 2007, 65.9% males (27 and 14); and both years, 60.2% males (62 and 41). For 2006, deviation from a 1:1 male:female ratio could not be demonstrated statistically (goodness-of-fit test, $G_1 = 1.04$, $P = 0.309$). However, for 2007, significantly more males were caught than females ($G_1 = 4.19$, $P = 0.041$). Likewise, for both years pooled, there were significantly more males than females ($G_1 = 4.31$, $P = 0.038$). No statistical heterogeneity was detected in sex ratio among years ($G_1 = 0.92$, $P = 0.338$), and overall sex ratio of adults (males:females) of captured individuals was 1.51:1.

For adult females, percentages of pregnant or lactating individuals were: 2006, 48.1% (13 of 27); 2007, 28.6% (4 of 14); and both years, 41.5% (17 of 41). No significant difference between years was demonstrable (Fisher's exact test, $P = 0.321$).

Mean mass of eight pregnant females was 40.17 ± 1.66 g, while 33 non-pregnant females averaged 35.63 ± 6.57 g; these two groups were not significantly different (one-way ANOVA, $F_{1,39} = 3.71$, $P = 0.061$). Mean mass for adult males was 37.48 ± 6.19 g ($n = 62$, range 22.7–51.0 g). For 95 adult animals (males and non-pregnant females), a two-way ANOVA detected no significant difference in mass for sex or year, nor was there significant interaction (respectively, $F_{1,91} = 1.30$, 0.03, and 0.86; $P = 0.257$, 0.859, and 0.356).

Movement, Abundance, and Density—Overall mean of average distances from centroid for adult males was 14.01 ± 10.35 m ($n = 47$, range 0–40.6 m), while that for adult females was 11.18 ± 5.69 m ($n = 31$, range 0–28.9 m). A two-way ANOVA detected no significant difference for sex, year, or interaction ($F_{1,74} = 0.02$–1.75, all $P > 0.050$). Average distances from centroid were not significantly different among grids (one-way ANOVA, $F_{4,73} = 0.19$, $P = 0.942$). Pooling *O. banderanus*, irrespective of sex or age, average distance from centroid was 12.74 ± 9.48 m ($n = 86$, range 0–40.6 m). Using this value, the effective area of a grid was estimated to be 1.320 ha.

Average distance moved between successive captures did not differ statistically between sexes (one-way ANOVA, $F_{1,239} = 2.64$, $P = 0.105$). Adult males moved 21.40 ± 21.95 m ($n = 132$, range 0–94.9 m), females 17.47 ± 13.83 m ($n = 109$, range 0–70.7 m), and both combined 19.62 ± 18.79 m ($n = 241$, range 0–94.9 m). We also did calculations weighing each individual equally with respect to movement between successive captures, but results were not appreciably different from those reported above.

Based on our model derived in program MARK, abundances for grids were 1.00–40.31 individuals/grid (Table 2). These values translate to density estimates of 0.76–30.55 individuals/ha with an average of 15.85 individuals/ha on grids where the species was present.

Co-occurring Species and Relative Abundance—There was a significant difference between years in the percent of small mammals captured that were *O. banderanus* (Fisher's exact test, $P < 0.001$), with the species comprising 16.5% (77 of 468) in 2006 and 5.5% (46 of 836) in 2007. The two localities (localities 14 and 17, Fig. 1) also significantly differed, with *O. banderanus* constituting 40.1% (61 of 149) of all small mammals at locality 14, but 5.4% (62 of

TABLE 3—Estimates, *SE*s, *Z*-scores, and *P*-values for constant and coefficients of independent variables incorporated sequentially in the logistic-regression equation when evaluating 2006–2007 trapping stations in Colima, Mexico, to predict the dependent variable logit (*Y*), which is the natural logarithm of the odds of Osgood's deermouse *Osgoodomys banderanus* being present.

Constant or independent variable	Coefficient ± *SE*	*Z*-score	*P*-value
Constant	−0.883 ± 0.296	−2.986	0.003
Percent grasses (X_3)	−0.027 ± 0.010	−2.671	0.008
Average distance to nearest tree (m) (X_{14})	−0.375 ± 0.076	−4.932	<0.001
Percent rocks (X_6)	0.025 ± 0.006	3.943	<0.001
Maximum canopy height (m) (X_{13})	0.041 ± 0.010	3.990	<0.001

1,155) at locality 17 (Fisher's exact test, $P < 0.001$). Relative abundance on grids varied as well, with *O. banderanus* comprising 0.6–43.4% of the small mammals.

Other species most commonly encountered in 2006–2007 were *Sigmodon mascotensis* (West Mexican cotton rat; 352 individuals; 27.0%), *Heteromys pictus* (painted spiny pocket mouse; 313; 24.0%), *Baiomys musculus* (southern pygmy mouse; 301; 23.1%), and *Reithrodontomys fulvescens* (fulvous harvest mouse; 131; 10.1%). Numbers of individuals captured of *Oryzomys couesi* (Coues' oryzomys; 34; 2.6%), *Tlacuatzin canescens* (gray mouse opossum; 29; 2.2%), *Nyctomys sumichrasti* (Sumichrast's vesper rat; 14; 1.1%), and *Hodomys alleni* (Allen's woodrat; 6; 0.5%) were lower than for *O. banderanus* (123; 9.4%). All of the above-mentioned species occurred on grids with *O. banderanus*.

Habitat—Contrasting means and *SD*s of the 14 environmental variables for the six grids where *O. banderanus* was present versus the four grids where it was not found, four significant differences were identified: mean percent grass, 12.0% for grids where present versus 47.2% for grids where absent ($F_{1,8} = 7.98$, $P = 0.022$); mean total hits high on a vertical pole, 5.14 versus 1.28 ($F_{1,8} = 9.86$, $P = 0.014$); mean average distance from nearest tree, 3.4 versus 6.9 m ($F_{1,8} = 11.63$, $P = 0.009$); and *SD* of percent forbs, 5.93 versus 15.10% ($F_{1,8} = 21.37$, $P = 0.002$). Thus, grids with *O. banderanus* present had less grass, thicker vegetation high above the ground, shorter distances to nearest tree, and less variation in percentage of forbs.

Evaluating mean values and *SD*s of environmental variables for trapping stations where *O. banderanus* was caught and not caught for 2006, 2007, and the combined years (Table 1), 10 variables were statistically different in all three comparisons. Ground cover at stations where *O. banderanus* was captured had lower percentages of grasses and higher percentages of leaf litter and rocks. In addition, capture sites relative to noncapture sites had fewer hits at 1 m, a more closed canopy, greater slope, fewer hits low and more hits high on a vertical pole, a higher canopy, and shorter average distance to nearest trees.

Stepwise logistic regression for 2006–2007 combined (10 grids, 1,000 trapping stations), contrasting stations where *O. banderanus* was caught and not caught, resulted in the following equation containing four of the 14 environmental variables:

$$\text{logit}(Y) = -0.883 - 0.027X_3 - 0.375X_{14} + 0.025X_6 + 0.041X_{13},$$

where logit (Y) is the natural logarithm of the odds of the species being present, X_3 is percent grass, X_{14} is average distance to nearest tree, X_6 is percent rocks, and X_{13} is maximum canopy height (Table 3). McFadden's ρ^2 was 0.263, indicating a robust model. Projection values for sites where *O. banderanus* was trapped tended to be greater than for those where the species was not caught (Fig. 3a). Coefficients for the first two variables were negative, indicating that stations where *O. banderanus* was trapped tended to have less grass (Fig. 3b) and closer trees (Fig. 3c). Coefficients for the last two environmental variables were positive, with stations where the species was caught typically having more rocks (Fig. 3d) and a higher canopy (Fig. 3e).

Using nonparametric multiplicative regression, the best model (log $B = 51.58$) for predicting likelihood of occurrence of *O. banderanus* incorporated three variables: average distance to nearest tree (tolerance 0.65), percent rocks (tolerance 7.20), and maximum canopy height (tolerance 8.75). Average neighborhood size of the resulting model was 73.5. Likelihood of occurrence of *O. banderanus* was highest (ca. 0.3–0.4) when on average trees were 1–3 m away, with likelihood falling sharply to <0.1 when trees were >4 m distant (Fig. 4a). For percent rocks (Fig. 4b), likelihood of occurrence tended to increase as percentage of rocks increased, with likelihood low (<0.3) in areas with <20% rocks and highest (0.7) at 80% rocks; however, areas with 90% rocks also had a low likelihood for occurrence. For maximum canopy height (Fig. 4c), likelihood of occurrence increased as canopy height rose with likelihood peaking above 0.5 when canopies were 32 m in height.

DISCUSSION—*Trapping Response*—Little information exists on arboreal activity of tropical rodents (Delany, 1971), which Domínguez-Castellanos et al. (2007) suggested could lead to a misrepresentation of population densities and activity patterns. We had equal numbers of ground and elevated traps, resulting in one-third of our captures of *O. banderanus* coming in elevated traps. Using traps placed 1–3 m above ground, Ceballos Gonzalez (1989) had a nearly identical proportion of captures from elevated traps (33.5%; $n = 95$) during monthly, 3-night studies (15 months total) on grids in deciduous and semideciduous forests at Chamela Biological Station in Jalisco. However, only ca. 20% of

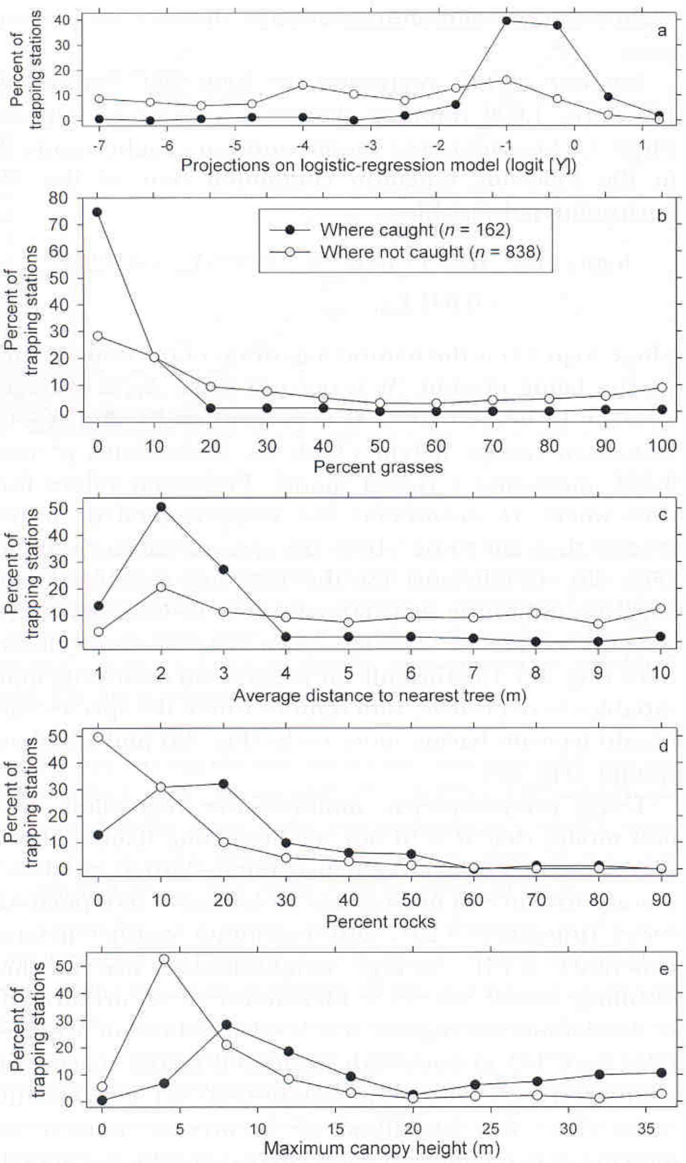

FIG. 3—a) Percentages of projections of trapping stations in a given class for the logistic-regression model based on data from 10 grids for 2006–2007 (1,000 trapping stations; 162 trapping stations where Osgood's deermouse *Osgoodomys banderanus* was caught and 838 where it was not caught). Resulting equation was logit $(Y) = -0.883 - 0.027X_3 - 0.375X_{14} + 0.025X_6 + 0.041X_{13}$, where logit (*Y*) is the natural logarithm of the odds of the species being present, X_3 is percent grasses, X_{14} is average distance to nearest tree, X_6 is percent rocks, and X_{13} is maximum canopy height. Subsequent panels show each variable taken individually: b) percent grasses; c) average distance to nearest tree; d) percent rocks; and e) maximum canopy height.

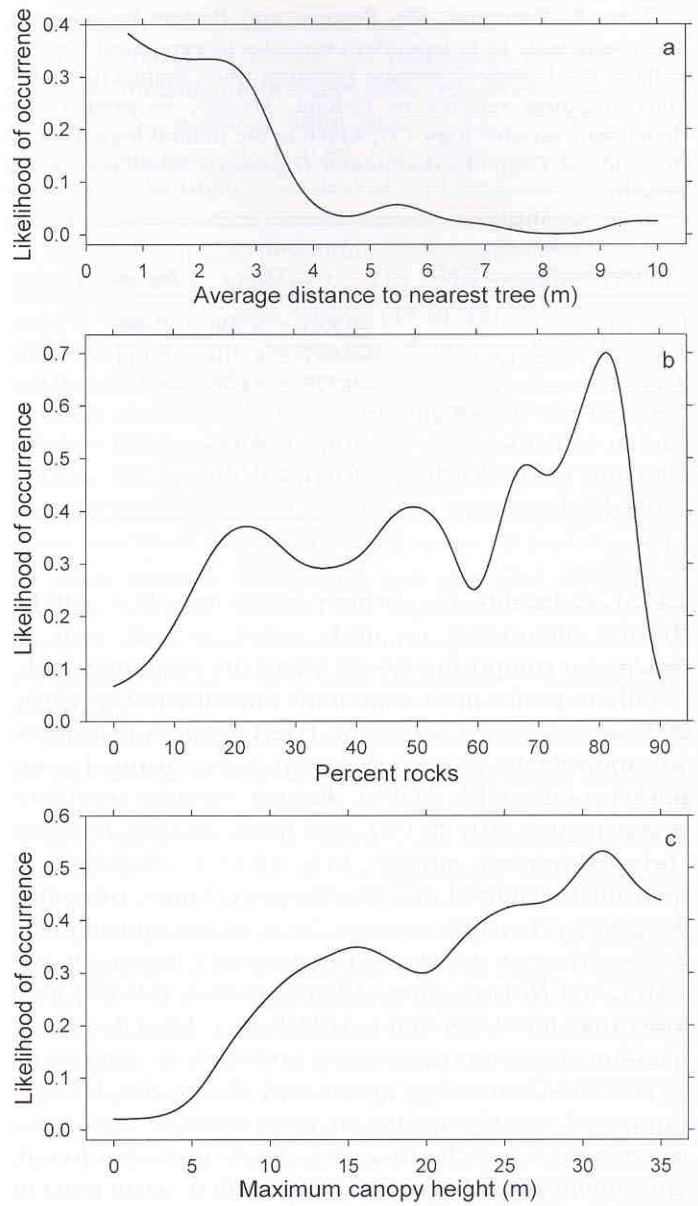

FIG. 4—Likelihood of occurrence of Osgood's deermouse *Osgoodomys banderanus* estimated relative to a) average distance to nearest tree, b) percent rocks, and c) maximum canopy height for a three-variable, nonparametric-multiplicative-regression model based on data from 10 grids for 2006–2007 (1,000 trapping stations, 162 where *O. banderanus* was caught and 838 where it was not caught).

his traps were placed above ground during his 20,412 trap-nights. Domínguez-Castellanos et al. (2007) reported a lower aboveground use for *O. banderanus* of 10% at Chamela Biological Station but did not indicate relative numbers of elevated and terrestrial traps. In Pará, Brazil, Lambert et al. (2005) compared species richness and rates of species accumulation using traps placed at three heights: ground, understory (similar to our elevated traps), and canopy. Many species of small mammals at their site were captured in the understory and rarely on the ground; however, no species was significantly more abundant in the canopy than in the understory traps, rendering understory traps as effective as canopy traps. Yet, in Manaus, Brazil, Malcolm (1991) reported that canopy trapping revealed a rich and abundant fauna not evident when traps were set on the ground or in the understory. However, there was little difference in numbers of species or individuals caught in ground and understory traps.

Over 68% of *O. banderanus* we captured more than once frequented both elevated and ground levels. For another semiarboreal species, *Reithrodontomys fulvescens*, we found a significantly lower proportion of animals (<49% of individuals) used both levels (Fisher's exact test, $P = 0.037$; unpublished data). It is clear that *O. banderanus* readily and regularly made use of both ground and elevated sites.

Probability of Capture Relative to Trapping Night and Moonlight—Some studies suggest that bright moonlit nights negatively affect trapping success for certain rodents (Blair, 1951; Price et al., 1984). Subsequently, fieldwork often has been conducted intentionally during the new moon when rates of capture are presumed to be highest (Prugh and Brashares, 2010), as done by Ceballos Gonzalez (1989) and Domínguez-Castellanos et al. (2007). We detected no relationship between lunar phase and probabilities of capturing *O. banderanus*. In an analysis of similar data from Colima (Januarys of 2003–2007), Schnell et al. (2008*b*) also detected no association for *Baiomys musculus*. It appears that the influence of moonlight on activity of small mammals is greater in more open habitats, such as deserts and grasslands.

In our 8-night study, night of trapping was a significant factor in the probability of catching *O. banderanus*, with probability of capture increasing nightly until night 6 or 7 and decreasing thereafter. Only a few comparable investigations have reported nightly temporal affects on trapping success. In an 8-night study during February in South Africa, van Hensbergen and Martin (1993) determined that probability of capturing the murid rodent *Rhabdomys pumilio* (xeric four-striped grass rat) increased steadily during nights 1–4 and decreased thereafter. Other studies conducted for 8-nights in Colima during January also found trapping night to influence significantly the probability of capturing *Baiomys musculus* (Schnell et al., 2008*b*) and *Sigmodon mascotensis* (Schnell et al., 2010*b*). Two basic patterns were documented in both species; probabilities of capture increased from nights 1–4 then decreased thereafter, or continued increasing until night 6 or 7 before decreasing.

Demographics and Movement—Mass of *O. banderanus* seldom has been documented. Davis (1944) examined six specimens and reported non-pregnant females in Guerrero averaged 43 g, while a pregnant female (in August) containing three nearly full-term embryos weighed 57.9 g (suggesting young weigh about 4 g each at birth). Ceballos Gonzalez (1989) reported average mass of 14 individuals in Jalisco to be 38.3 ± 5.6 g, a value similar to our average mass of adults of 37.1 g.

Reproduction in *O. banderanus* likely occurs year-round with the reproductive pattern reported to be continual polyestrous (Mendoza Durán and Miranda, 2002; Arroyo-Cabrales, 2005). Of females we captured in January, >40% were reproductively active. This is similar to another study conducted during January by Sánchez-Hernández et al. (2009) at Ejido Ranchitos, Colima. They reported that about one-third of 44 female *O. banderanus* were pregnant, lactating, or both.

Overall, males significantly out-numbered females 1.51:1 in our traps, and nearly 2:1 in 2007. Sánchez-Hernández et al. (2009) reported a 1.41:1 sex ratio (62 males, 44 females), although this was not statistically different from 1:1 (goodness-of-fit test, $G_1 = 3.07$, $P = 0.080$). Ceballos Gonzalez (1989) reported the overall sex ratio of *O. banderanus* in semideciduous forest to be 1.36:1 (19 males, 14 females), while Domínguez-Castellanos et al. (2007) obtained 1:1.28 (25 males, 32 females); neither differ statistically from 1:1. The explanation often given for a male-skewed sex ratio in natural populations is that males travel over larger areas than females and, thus, have greater exposure to traps (Terman, 1968). Ceballos Gonzalez (1989) noted that female *O. banderanus* were caught more frequently; we also had a higher average number of captures per individual for females. Thus, exposure to traps per se does not explain the deviation in sex ratio. However, in our study, male *O. banderanus* moved farther on average than females, albeit the difference was not statistically significant.

Ceballos Gonzalez (1989) concluded that male *O. banderanus* moved farther than females, but no statistical test was reported. He calculated an average distance moved between successive captures of 24.0 ± 15.3 m for males (greater than our 21.40 m), 15.4 ± 13.5 m for females (less than our 17.47 m), and an overall mean distance between successive captures of 17.8 m ($n = 107$; slightly lower than our 19.62 m). Domínguez-Castellanos et al. (2007) marked animals with fluorescent powder, released them, and measured distances traveled. They too reported longer average distances for males (14.74 m) than females (9.95 m), but these were not statistically different. In addition, they determined that *O. banderanus* moved significantly farther during the dry season than the wet (15.2 ± 11.9 versus 7.0 ± 5.3 m, respectively) and farther in deciduous forest than in semideciduous forest (19.7 ± 13.7 versus 8.6 ± 6.5 m). For trapping grids in Jalisco, Collett et al. (1975) reported that one individual traveled 27.3 m between capture sites and another 68.3 m, both values within the range of our data.

Abundance and Density—Ceballos Gonzalez (1989) provided density estimates for *O. banderanus* in semideciduous forest using minimum number of individuals known to be alive. He reported a January density of 3 individuals/ha and a yearly average of 2.1 individuals/ha, estimates considerably lower than our overall average of 15.9 individuals/ha, but within the range of densities among our grids (0.8–30.6 individuals/ha). Ceballos Gonzalez (1989) also recorded changes in density over a 14-month period, noting an increase from low values in

December beginning in January to a peak of 8 individuals/ha in March.

Domínguez-Castellanos et al. (2007) caught 57 *O. banderanus* on four 1-ha plots, which extrapolates to 14.3 individuals/ha and is a value similar to our overall estimate of density. Collett et al. (1975) caught 11 individuals on three trapping grids with effective areas of 3.11 ha (1.18 individuals/ha).

Co-occurring Species and Relative Abundance—Osgoodomys banderanus is considered common in humid areas like tropical semideciduous forests while scarce with patchy distributions in deciduous forests (Ceballos Gonzalez, 1989; Ceballos and Miranda, 2000). In north-central Colima, we found the relative abundance of *O. banderanus* to vary significantly between nearby localities and between years, with the species ranking fifth overall in abundance of small mammals. Such variation in abundance is likely in large part due to habitat heterogeneity. At Ejido Ranchitos, Colima, *O. banderanus* was the most abundant species (Sánchez-Hernández et al., 2009), comprising 26.1% of 406 individuals of all species. Domínguez-Castellanos et al. (2007) reported *O. banderanus* and *Peromyscus perfulvus* (tawny deermouse) to be the most abundant species in both the deciduous and semi-deciduous forests of Jalisco. Also in Jalisco, Ceballos Gonzalez (1989) noted that *O. banderanus* ranked third in terms of biomass (g/ha) and comprised 9.2% of individuals captured. He reported *O. banderanus* to be most similar to *Xenomys nelsoni* (Magdalena woodrat), *Nyctomys sumichrasti*, and *Reithrodontomys fulvescens* in use of habitat. Hooper (1968) considered *O. banderanus* to be associated ecologically with *P. perfulvus*, which in Colima is restricted to coastal areas (Schnell et al., 2008*a*) and where *O. banderanus* occurs together with it. In Michoacán, Winkelmann (1962) found *O. banderanus* along with *Heteromys pictus* and *Hodomys alleni*.

Habitat—Average distance to nearest tree was a significant variable in habitat preference, with capture sites having closer trees. Percent rocks and maximum canopy height were of importance, with *O. banderanus* occupying areas with more rocks and higher canopies. *Osgoodomys banderanus* also chose microhabitats with less grass, more leaf litter, and more dead wood. The species has been reported to build burrows between rocks or construct nests (lined with leaves and other plant material) under accumulations of litter on the forest floor and in hollows of trees (Ceballos Gonzalez, 1989; Ceballos and Miranda, 2000).

Ceballos Gonzalez (1989) frequently found *O. banderanus* in rocky habitats, concluding its distribution was restricted to areas with rocks or large accumulations of brush on the ground. Collett et al. (1975) reported more often capturing the species in parts of grids with higher elevations. Winkelmann (1962) caught *O. banderanus* at Cañon de Zopilote, Guerrero, near a stream that was surrounded by scrub forest and cacti-covered rocky hillsides. He also found *O. banderanus* at lower elevations in the mountains of Michoacán along a boulder-strewn stream with humid tropical vegetation. Davis (1944:397) reported sampling 44 locations along both coasts and the interior of Mexico, finding six *O. banderanus* at Río Aguacatillo in Guerrero. He remarked, "The nearly impenetrable brushy hillsides at this station harbored numbers of these long-tailed mice. Apparently this species is restricted to such a habitat as none were taken elsewhere."

Thus, *O. banderanus* has a strong microhabitat preference for rocky areas at various localities in Mexico, including Colima. We found areas frequented by *O. banderanus* to possess other important characteristics as well, such as a more open understory (with less dense ground cover) that is well enclosed by nearby trees that form a tall canopy.

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Appendix—Gazetteer with localities in Colima, Mexico, where *Osgoodomys banderanus* (Osgood's deermouse) has been captured. Locality numbers correspond to those in Fig. 1 (locality numbers with appended lowercase letters were geographically close and are represented by a single circle identified by locality number on the map). Localities are ordered by municipality. Latitude and longitude in decimal degrees are included in brackets.

Comala: (1) Hacienda San Antonio [19.4482042°N, 103.7166515°W].

Minatitlán: (2) El Sauz, 8 km NE Minatitlán, 1,200 m, 19°26.33′N, 103°60.00′W [19.4388333°N, 104.0000000°W]; (2a) 8.5 km NE El Sauz, 1,200 m, 19°26.33′N, 103°60.00′W [19.4388333°N, 104.0000000°W]; (3) Rastrojitos, 3 km NW Ranchitos, 1,650 m [19.4261665°N, 103.9898427°W]; (4) Rastrojitos, 2 km NW Ranchitos, 1,650 m [19.4202113°N, 103.9763057°W]; (5) 1 km NW Ranchitos, 1,550 m [19.4119396°N, 103.9690770°W]; (6) El Salto, 4 km WSW Minatitlán, 630 m, 19°22.16′N, 104°5.06′W [sic; 19.3658099°N, 104.0829117°W]; (7) 9 km SW Minatitlán, 810 m, 19°19.71′N, 104°6.81′W [19.3285000°N, 104.1135000°W]; (7a) 7 km SW Minatitlán, 780 m, 19°20.76′N, 104°6.15′W [19.3460000°N, 104.1025000°W].

Villa de Álvarez: (8) 11 miles [17.7 km] W Comala [19.3156336°N, 103.9351103°W].

Cuauhtémoc: (9) 2 km E Palmillas, 950 m 19°21.25′N, 103°31.58′W [19.3541667°N, 103.5263333°W]; (10) 6 km S Cuauhtémoc, 710 m, 19°16.083′N, 103°36.000′W [19.2680500°N, 103.6000000°W]; (11) 2.5 km SE Palmillas, 950 m, 19°20.05′N, 103°32.22′W [19.3341667°N, 103.5370000°W]; (12) 4.5 km SE Palmillas, 860 m, 19°19.67′N, 103°31.36′W [19.3278333°N, 103.5226667°W]; (12a) 4 km SE Palmillas, 860 m, 19°19.67′N, 103°31.36′W [19.3278333°N, 103.5226667°W]; (12b) 4.5 km SE, 1 km E Palmillas, 850 m, 19°19.65′N, 103°31.19′W [19.3275000°N, 103.5198333°W]; (12c) 4.5 km SE, 0.5 km E Palmillas, 850 m, 19°19.67′N, 103°31.36′W [19.3278333°N, 103.5226667°W]; (12d) 4.5 km SE, 0.5 km S Palmillas, 850 m, 19°19.67′N, 103°31.36′W [19.3278333°N, 103.5226667°W]; (12e) 5 km SE Palmillas, 860 m, 19°19.59′N, 103°31.40′W [19.3265000°N, 103.5233333°W]; (12f) 5.5 km SE, 1 km E, Palmillas, 810 m, 19°19.38′N, 103°31.10′W [19.3230000°N, 103.5183333°W]; (12g) 5.5 km SE, 1.5 km E Palmillas, 810 m, 19°19.38′N, 103°31.10′W [19.3230000°N, 103.5183333°W]; (13) 5.5 km SE Cerro Colorado, 763 m, 19°17.714′N, 103°31.470′W [19.2952333°N, 103.5245000°W]; (13a) 2.5 km SE Cerro Colorado, 873 m, 19°18.864′N, 103°32.548′W [19.3144000°N, 103.5424667°W]; (13b) 2.2 km SE Cerro Colorado, 887 m, 19°19.155′N, 103°32.633′W [19.3192500°N, 103.5438833°W]; (14) Rancho La Angostura, 761 m, 19°18.837′N, 103°39,997′W [19.3139500°N, 103.6666167°W]; (15) El Cóbano [19.3043871°N, 103.6412551°W]; (16) El Cóbano, 2.25 km E Hacienda El Cóbano [19.3051127°N, 103.6301534°W]; (17) Colima airport, Colima, Mexico, 19°16′3.5″N, 103°35′54.5″W [19.2676389°N, 103.5984722°W]; (17a) Colima airport, Grid 1 in 2007, Colima, Mexico, 19°16′56.3″N, 103°34′3.9″W [19.2823056°N, 103.5677500°W]; (17b) Colima airport, Grid 4 in 2007, Colima Mexico, 19°17′2.8″N, 103°34′28.4″W [19.2841111°N, 103.5745556°W].

Manzanillo: (18) 4.5 km N Los Parajes [19.2757042°N, 104.4209372°W]; (19) El Charco, 50 feet [15 m] [19.2439085°N, 104.4945587°W]; (20) 2 km NW Los Parajes [19.2440141°N, 104.4400682°W]; (20a) 4 km NW Los Parajes, 19°15′38″N, 104°25′40″W [19.2605555°N, 104.4277777°W]; (21) Don Tomás, 270 m, 19°13′43″N, 104°23′28″W [19.2286111°N, 104.3911111°W]; (21a) 1 km WNW Don Tomás, 265 m, 19°13′58″N, 104°23′56″W [19.2327778°N, 104.3988889°W]; (22) La Tigrera, 2 km SW Don Tomás, 19°13.26′N, 104°24.35′W [19.2210000°N, 104.4058333°W]; (23) La Huiscolotila [19.2211967°N, 104.3783889°W]; (24) 4 km E Don Tomás, 19°12′51″N, 104°22′03″W [19.2141667°N, 104.3675000°W]; (24a) 1.6 km SE La Huiscolotila, 250 m, 19°12.73′N, 104°21.93′W [19.2121667°N, 104.3655000°W]; (25) 2 miles [3.2 km] NE Camotlán [19.2305986°N, 104.2052184°W]; (26) 3.4 km SE Las Canoas, 550 m, 19°13.88′N, 104°7.6′W [19.2313333°N, 104.1266667°W]; (26a) 2.6 km SE Las Canoas, 630 m, 19°13.89′N, 104°8.4′W [19.2315000°N, 104.1400000°W]; (27) 3 km WNW San José de Lumbert, 480 m [19.1897183°N, 104.1418881°W]; (28) 0.6 km NE La Rosa, 700 m, 19°11.523′N, 104°6.225′W [19.1920500°N, 104.1037500°W]; (28a) 0.5 km NE La Rosa, 893 m, 19°11.483′N, 104°6.146′W [19.1913833°N, 104.1024333°W]; (28b) Río San José, 0.3 km NE La Rosa, 893 m, 19°11.483′N, 104°6.146′W [19.1913833°N, 104.1024333°W]; (29) 4 km NW (by road) San José de Lumbert, 19°10.54′N, 104°9.23′W, 466 m [sic; 19.1821634°N, 104.1534429°W]; (30) Casa del Señor Raúl Ochoa Duarte, San José de Lumbert, 555 m, 19°10.922′N, 104°7.677′W [19.1820333°N, 104.1279500°W]; (31) Playa de Oro, 19°7.935′N, 104°30.786′W [19.1322500°N, 104.5131000°W]; (31a) Playa de Oro, 19°8.028′N, 104°30.484′W [19.1338000°N, 104.5080667°W]; (31b) Playa de Oro, 3 m, 19°7.947′N, 104°30.802′W [19.1324500°N, 104.5133667°W]; (31c) Playa de Oro, 0 m [19.1391333°N, 104.5288167°W]; (31d) 3 km NE Playa de Oro, 19°8.698′N, 104°30.558′W [19.1449667°N, 104.5093000°W]; (31e) Playa de Oro, 19°7.987′N, 104°31.130′W [19.1331167°N, 104.5188333°W]; (31f) 0.5 km E Playa de Oro [19.1331167°N, 104.5188333°W]; (32) 1.3 km E Playa de Oro, 80 m, 19°8.424′N, 104°30.260′W [19.1404000°N, 104.5043333°W]; (32a) Playa de Oro, Torrecillas [19.1404000°N, 104.5043333°W]; (33) 4 km SW La Central, 40 m, 19°7.514′N, 104°27.811′W [19.1252333°N, 104.4635167°W]; (34) Rancho Majagua, 19°6.335′N, 104°26.814′W [19.1055833°N, 104.4469000°W]; (34a) 0.5 mile [0.8 km] S, 7 miles [11.2 km] W Santiago, 0 m [19.1055900°N 104.4469000°W]; (35) 1 mile [1.6 km] NE Santiago, 3 m [19.1275000°N, 104.3378162°W]; (36) 3 km E Santiago [19.1209963°N, 104.3320529°W]; (37) 5 miles [8 km] N Manzanillo [19.1126522°N, 104.3161933°W]; (38) 1 km W Paso Ancho, 80 m [19.0710620°N, 104.1787780°W]; (39) Agua Blanca, 141 m, 19°3.961′N, 104°3.152′W [19.0660167°N, 104.0525333°W]; (40) Manzanillo [19.0536130°N, 104.3167120°W].

Coquimatlán: (41) 9 km W Pueblo Juárez [19.1672522°N, 104.0171270°W]; (42) La Fundición, 19°8.498′N, 104°1.179′W [19.1416333°N, 104.0196500°W]; (43) Pueblo Juárez [19.1674296°N, 103.9314468°W]; (43a) Hacienda La Magdalena [19.1674296°N, 103.9314468°W]; (44) 2 km NW La

Esperanza, 260 m [19.1768310°N, 103.8815742°W]; (45) 2.8 km WSW Coquimatlán, 300 m, 19°11.5′N, 103°50.2′W [19.1916667°N, 103.8366667°W]; (46) 3 km NE Jala, 300 m, 19°9.141′N, 103°49.92′W [19.1523500°N, 103.8320000°W]; (46a) 3.5 km NE Jala, 460 m, 19°9.809′N, 103°49.744′W [19.1634833°N, 103.8290667°W].

Colima: (47) 3.5 miles [5.6 km] NNW Colima [19.2751824°N, 103.7167014°W]; (48) Colima [19.2559340°N, 103.7140066°W]; (49) near Colima [19.2379963°N, 103.6881541°W]; (50) 6.5 km N Trapichillas, 627 m, 19°12.844′N, 103°31.329′W [19.2140667°N, 103.5221500°W]; (51) 1.5 km S, 3.0 km E Asmoles, 359 m [19.1044700°N, 103.7472000°W]; (52) 3 km NE Tepames, 480 m, 19°6.522′N, 103°35.677′W [19.1087000°N, 103.5946167°W]; (52a) 3.5 km NE Tepames, 460 m, 19°7.020′N, 103°35.754′W [19.1170000°N, 103.5959000°W]; (53) 1.4 km S Puerta de Anzar, 244 m, 19°4′54″N, 103°32′18″W [sic; 19.1065310°N, 103.5526624°W]; (53a) 2 km SE Puerta de Anzar, 460 m, 19°6.021′N, 103°32.301′W [19.1003500°N, 103.5383500°W]; (54) 1 km E El Hervidero, 5 km S Puerta de Anzar, 19°4.854′N, 103°32.153′W [19.0809000°N, 103.5358833°W]; (54a) El Hervidero, 5 km S Puerta de Anzar, 244 m, 19°4′54″N, 103°32′18″W [19.0816667°N, 103.5383333°W]; (54b) 1 km NNW El Hervidero, 400 m, 19°5.130′N, 103°32.375′W [19.0855000°N, 103.5395833°W].

Armería: (55) 5 miles [8.0 km] NE La Cofradía (Juárez) [19.0358290°N, 103.9156623°W]; (56) La Taberna, 8 km N Nuevo Cuyutlán, 250 m, 19°4.082′N, 104°7.077′W [sic; 19.0208203°N, 104.0346901°W].

Tecomán: (57) 4.5 km N, 5 km E Tecolapa, 300 m [19.0546667°N, 103.7833333°W]; (58) 0.5 km E Tecomán [18.9747918°N, 103.8673673°W]; (59) 4 km E Tecomán, 10 m [18.9239492°N, 103.8489101°W]; (59a) 5 km E Tecomán, 10 m, 18°56.13′N, 103°49.84′W [18.9355000°N, 103.8306667°W] (60) 3 km NE Tecuanillo, 10 m, 18°50.10′N, 103°53.49′W [18.8350000°N, 103.8915000°W].

Ixtlahuacán: (61) 4.3 km NE Las Conchas, 133 m, 18°54′37.98″N, 103°36′08.32″W [18.9105500°N, 103.6023111°W]; (61a) 3.9 km NE La[s] Concha[s], 73 m, 18°54′40.36″N, 103°36′26.99″W [18.9112111°N, 103.6074972°W]; (62) 1.6 km NE Las Conchas, 30 m [18.8974644°N, 103.6205008°W]; (63) 3.3 km NW La[s] Concha[s], 60 m, 18°54′20.3″N, 103°39′19.3″W [18.9056389°N, 103.6553611°W].