BIAS IN THE DETERMINATION OF TEMPORAL ACTIVITY PATTERNS OF SYNTOPIC *PEROMYSCUS* IN THE SOUTHERN APPALACHIANS

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We compared inferred activity patterns of two syntopic rodents, *Peromyscus leucopus* and *P. maniculatus,* in western North Carolina. Activity patterns were derived from capture-frequency data obtained from Sherman live-traps equipped with digital timers following different trapping protocols. We tested the hypothesis that no differences would be observed in frequency distribution of captures from trapping grids monitored only in the morning (control) compared with grids where captured animals were released during the night and in the morning (treatment). Distributions of frequencies of captures on control and treatment grids were significantly different. On control grids, capture frequencies (based on 3-h intervals) of both species were higher in the first 3 h after sunset and decreased thereafter throughout the night, but frequencies of captures of both species were uniform throughout the night on treatment grids. Photographic records from automated cameras suggested increasing levels of activity throughout the night. Activity patterns derived from camera data were different from those derived from the control and treatment grids. Inferences regarding activity patterns are sensitive to method and trapping-protocol bias.

Key words: *Peromyscus leucopus, Peromyscus maniculatus,* activity patterns, automated camera system, North Carolina, southern Appalachians

Bruseo and Barry (1995) recently documented nocturnal activity patterns of two syntopic rodent species, the white-footed mouse, *Peromyscus leucopus noveboracensis,* and the deer mouse, *P. maniculatus nubiterrae,* using live traps with digital timers in the central Appalachian Mountains. They reported that nocturnal activity patterns of *P. leucopus* were essentially unimodal, with the greatest peak 1–2 h after sunset and decreasing thereafter throughout the night. Furthermore, distribution of captures of *P. leucopus* among seasons did not vary. Those authors reported that activity patterns of *P. maniculatus* varied somewhat among seasons. Throughout most of the year, activity of *P. maniculatus* was similar to *P. leucopus*; it was highest 1–3 h after sunset and generally decreased thereafter. In spring, there were significant differences in activity observed between the two species; peak activity for *P. maniculatus* occurred about 7 h after sunset. The unimodality of activity of *P. leucopus* and somewhat variable activity of *P. maniculatus* observed by Bruseo and Barry (1995) suggests that temporal niche partitioning may allow coexistence of syntopic species that otherwise occupy similar ecological niches.

In spring 1996, we conducted preliminary studies of activity patterns of syntopic *P. leucopus* and *P. maniculatus* in the southern Appalachian Mountains. We compared temporal activity data obtained from snap traps equipped with digital timers with data derived from automated cameras. Data from our timer traps closely corresponded to data of Bruseo and Barry (1995); both *P. leucopus* and *P. maniculatus* exhibited a peak in activity within the first 2 h after sunset with a resurgence of activity in the hours before sunrise. However, data from

automated cameras showed an opposing trend of steadily increasing activity from sunset throughout the night. We hypothesized that data relating to activity patterns of small mammals may be biased by differences in the method of data collection; specifically, that differences would be observed in activity patterns based on distribution of captures derived from timer traps checked only in the morning (Bruseo and Barry, 1995) compared with traps monitored during night and morning (Drickamer, 1987). We conjectured that those differences would result from animals being captured soon after sunset, because activity of animals trapped early in the evening could not be recorded later in the night. Furthermore, animals active later in the night might go unrecorded if traps were occupied. We further postulated that observations of nocturnal activity by automated cameras could be used as an independent assessment of activity patterns in these two species. Therefore, in summer 1996, we initiated a controlled study comparing data relating to activity patterns of *P. leucopus* and *P. maniculatus* derived from live traps equipped with digital timers that were checked only in the morning (control) compared with similar traps checked mid-night and morning (treatment). We compared these patterns with activity data derived from automated cameras equipped with time-recording devices.

Materials and Methods

This study was conducted at two sites, one in the Coweeta Creek Basin and another in the Wine Spring Creek Basin of the Nantahala National Forest in Macon Co., North Carolina. Vegetative cover at both sites was that normally associated with high-elevation northern hardwood communities. Yellow birch (*Betula alleghaniensis*), black birch (*B. lenta*), black cherry (*Prunus serotina*), red maple (*Acer rubrum*), northern red oak (*Quercus rubra*), and American beech (*Fagus grandifolia*) were common canopy dominants. Striped maple (*A. pennsylvanicum*), mountain maple (*A. spicatum*), eastern hemlock (*Tsuga canadensis*), and rosebay rhododendron (*Rhododendron maximum*) were common components of the midstory in mesic localities, but mountain laurel (*Kalmia latifolia*) and flame azalea (*R. calendulaceum*) were found on drier sites. A rich herbaceous understory was well developed. These sites supported moderate densities (null model of CAPTURE—Otis et al., 1978) of *Peromyscus leucopus leucopus* (33 mice/ha) and *P. maniculatus nubiterrae* (43 mice/ha). *P. maniculatus* was differentiated from *P. leucopus* based on the presence of a longer and more sharply bicolored tail (Laerm and Boone, 1994). There was no significant difference between control and treatment grids when density estimates for the two species were compared.

Between 8 July–11 August 1996, we used Sherman live-traps equipped with digital timers to determine time of capture. We followed the design of Barry et al. (1989) except that we used non-folding instead of folding traps and solid-strand instead of braided wire between the timer and switch. Traps were baited with rolled oats and placed on three pairs of square 7- by 7-station grids with 10-m spacing. Grid pairs were located ca. 100 m apart in the same vegetative community and were assigned randomly to control or treatment. Traps were run for 5 consecutive nights on each grid, and we trapped each pair of grids simultaneously to eliminate temporal variation. Traps on control grids were checked each morning (within 1 h of sunrise), but traps on treatment grid were checked once during the night (4–5 h after sunset), and the following morning. Because checking traps during the night may disrupt natural activity of mice (Bruseo and Barry, 1995), we attempted to equalize disturbance by walking the control grids at night. When we checked traps at night on control grids, no animals were released. For each capture, we recorded species, age, sex, body mass, reproductive status, and time of capture. A uniquely numbered fingerling tag was attached to the base of an ear for identification. All animals were released at the point of capture.

Camera stations consisted of an infrared switch and event recorder attached to a camera (Trailmaster, Lenexa, KS). We increased responsiveness of those units by restricting the width of the beam emitted by the infrared transmitter unit. We placed two vertical strips of electrical tape across the lens leaving a 3-mm slit across the center. Best results were achieved with a

pulse-delay setting of 15 and a camera delay setting of 5 min. Use of shorter settings resulted in the exposure of all film before the end of the night; hence, those records were omitted from the data set. Camera stations were placed at nine locations in the same vegetative community as the grids and >300 m from the grids. Camera stations were established between 8–18 July 1996 and were baited with rolled oats.

Statistical comparisons were made by grouping capture frequencies into 3 h intervals. We tested the null hypothesis of no difference in distribution of captures over time between control and treatment methods. Data analysis consisted of log-likelihood ratio comparisons (G^2—SAS Institute, 1989). Results were considered significant at $P \leq 0.05$. All activity times were converted into hours past sunset using data obtained from the United States Naval Observatory in Washington, D.C. Coordinates used for determining time of sunset were 83.5°W, 35.1°N for the study site at Coweeta and 83.6°W, 35.2°N for the site at Wine Spring Creek Basin.

Results

From 1,470 trap nights, we recorded 122 captures of *P. maniculatus* (72 treatment, 50 control) and 50 captures of *P. leucopus* (37 treatment, 13 control). Those included 40 initial captures and 32 recaptures of *P. maniculatus* for the treatment, and 32 initial captures and 18 recaptures for the control. Captures of *P. leucopus* included 19 initial captures and 18 recaptures for the treatment and 11 initial captures with two recaptures for the control. Species captured incidentally included the woodland jumping mouse (*Napaeozapus insignis*), southern red-backed vole (*Clethrionomys gapperi*), golden mouse (*Ochrotomys nuttali*), northern short-tailed shrew (*Blarina brevicauda*), masked shrew (*Sorex cinereus*), and smoky shrew (*Sorex fumeus*).

We obtained 61 photographic observations of *Peromyscus* from one night at each of the nine camera stations. Because we were unable to differentiate *P. leucopus* from *P. maniculatus* in many of the photographs, we pooled those observations.

For each species, there were no sex or age differences in distribution of capture frequencies for either treatment (sex, $G^2 = 1.96$, $d.f. = 2$, $P = 0.38$; age, $G^2 = 4.84$, $d.f. = 4$, $P = 0.31$) or control grids (sex, $G^2 = 0.55$, $d.f. = 2$, $P = 0.76$; age, $G^2 = 0.40$, $d.f. = 4$, $P = 0.98$). Therefore, data were combined for each species within each trapping method. We compared frequencies of capture of both species over time for the control and treatment (Fig. 1). No differences were observed between species for the treatment ($G^2 = 0.12$, $d.f. = 2$, $P = 0.94$) or control ($G^2 = 0.10$, $d.f. = 2$, $P = 0.95$). We therefore pooled the data from both species for comparison with the camera data (Fig. 2).

In the control, capture frequencies of both *P. leucopus* and *P. maniculatus* peaked 1–3 h after sunset and then declined (Figs. 1a and 1b). Significant differences were observed in distribution of those frequencies when examined by 3-h time blocks (Figs. 1a and 2a). Capture frequencies were higher in the first 3 h after sunset for both species compared with later in the night. In the treatment, frequency of capture of both species appeared bimodal (Figs. 1c and 1d), but the difference in the three 3-h time periods throughout the night was not significantly different from expected ($G^2 = 1.167$, $d.f. = 2$, $P = 0.56$). However, distribution of frequencies of capture was different from that expected from a random (uniform) distribution for the control ($G^2 = 18.961$, $d.f. = 2$, $P < 0.001$). Comparisons among activity patterns derived from camera data and the control and treatment grids (Fig. 2) also differed ($G^2 = 53.381$, $d.f. = 2$, $P < 0.001$).

Discussion

Our study indicates that inferences regarding activity patterns derived from timer-equipped live-traps are sensitive to methodology (Fig. 2). Based upon our control method, we concur with observations of Bruseo and Barry (1995) that activity, as inferred from capture-frequency data, peaks within a few hours after sunset and then decreases throughout the night. However,

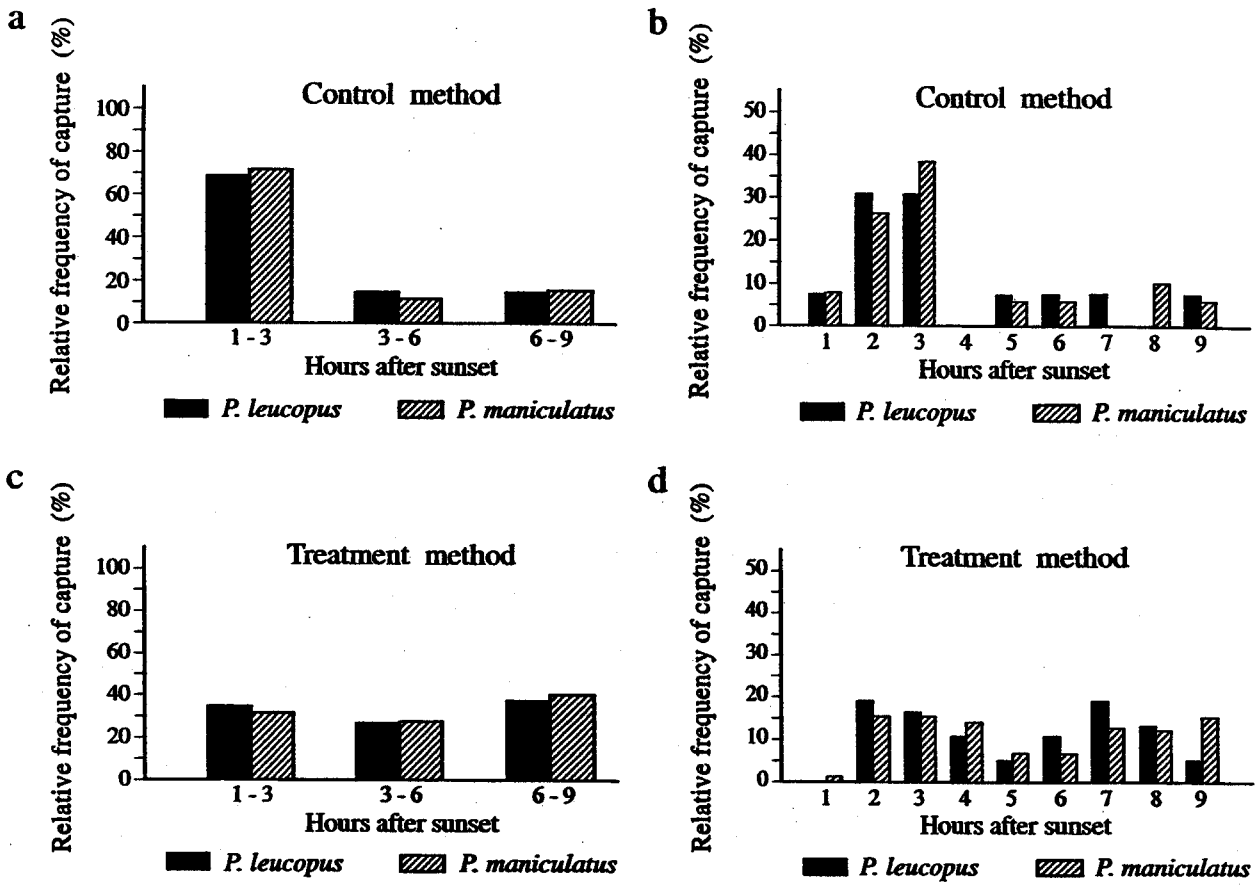

FIG. 1.—Comparisons of relative frequencies of capture over time of *Peromyscus leucopus* and *P. maniculatus*: a) control trapping method in 3-h blocks, b) control trapping method in 1-h blocks, c) treatment trapping method in 3-h blocks, and d) treatment trapping method in 1-h blocks in Macon Co., North Carolina, 1996.

frequencies of capture derived from the treatment method suggest activity patterns do not differ throughout the night. Furthermore, inferences drawn from camera data suggest another pattern of increasing activity throughout the night.

Differences observed between control and treatment data are attributable to several causes. First, because traps on the control grid caught increasing numbers of mice in the first few hours after sunset, fewer traps were available to catch mice later in the night (this problem would be exacerbated where densities of mice are moderate to high). Second, because mice caught in the first few hours after sunset remained in traps, these animals could not be caught later in the night. We conclude that this trapping protocol biases inferences regarding activity patterns (i.e., it inflates capture frequencies early in the night relative to those later in the night). Checking traps and releasing captured mice in the middle of the night reduces these problems. This method provides animals not yet trapped increased access to open traps and also allows recording of the late-night activity of animals released. We are sensitive to the concerns of Gilbert et al. (1986) and Bruseo and Barry (1995) that checking traps in the middle of the night may disturb natural activity patterns of mice. However, such criticisms are moderated by the high degree of correspondence between our data for the control experiment and that of Bruseo and Barry (1995), and the fact that we controlled for this effect in our comparison of control and treatment. Increasing levels of activity reflected by camera data do not necessarily provide an independent assessment of activ-

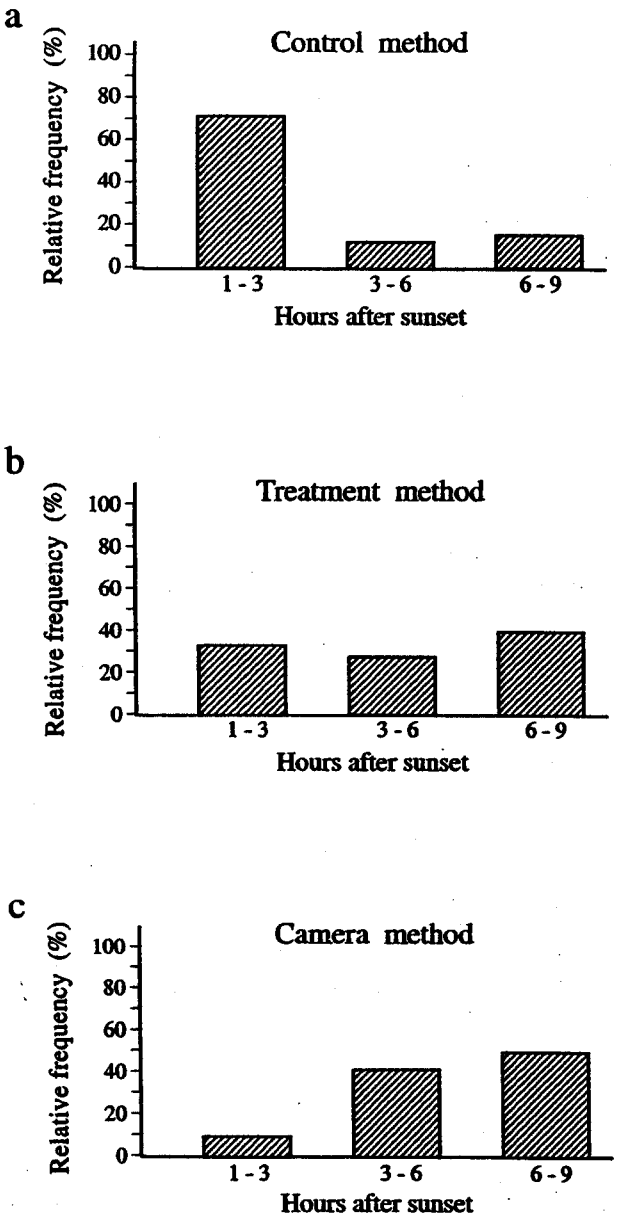

FIG. 2.—Comparisons of relative frequencies of occurrence over time of camera and trapping methods for *Peromyscus* in 3-h blocks: a) control trapping method, b) treatment trapping method, and c) camera method in Macon Co., North Carolina, 1996.

ity patterns compared with traps. Rather, we suggest that the continuous increase in activity of *Peromyscus* shown by cameras (Fig. 2c) reflects an alteration of natural activity patterns in response to an anomalous resource (bait). It is likely that increasing numbers of mice discovered or revisited the bait pile throughout the night, resulting in increased frequency of observations (photographs) as the night progressed.

Levels of significance for frequencies of captures (observations) indicate that inferences regarding activity patterns of small mammals using timer-traps are subject to bias inherent in methodological protocol. We believe that data obtained from the treatment grid were the least biased of our three methods, and thus that which most closely reflect activity patterns of these two *Peromyscus* in the southern Appalachian Mountains.

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