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Original Article

Influence of Trap Modifications and Environmental Predictors on Capture Success of Southern Flying Squirrels

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ABSTRACT Sherman traps are the most commonly used live traps in studies of small mammals and have been successfully used in the capture of arboreal species such as the southern flying squirrel (*Glaucomys volans*). However, southern flying squirrels spend proportionately less time foraging on the ground, which necessitates above-ground trapping methods and modifications of capture protocols. Further, quantitative estimates of the factors affecting capture success of flying squirrel populations have focused solely on effects of trapping methodologies. We developed and evaluated the efficacy of a portable Sherman trap design for capturing southern flying squirrels during 2015–2016 at the Alice L. Kibbe Field Station, Illinois, USA. Additionally, we used logistic regression to quantify potential effects of time-dependent (e.g., weather) and time-independent (e.g., habitat, extrinsic) factors on capture success of southern flying squirrels. We recorded 165 capture events (119 F, 44 M, 2 unknown) using our modified Sherman trap design. Probability of capture success decreased 0.10/1° C increase in daily maximum temperature and by 0.09/unit increase (km/hr) in wind speed. Conversely, probability of capture success increased by 1.2/1° C increase in daily minimum temperature. The probability of capturing flying squirrels was negatively associated with trap orientation. When tree-mounted traps are required, our modified trap design is a safe, efficient, and cost-effective method of capturing animals when moderate weather (temp and wind speed) conditions prevail. Further, we believe that strategic placement of traps (e.g., northeast side of tree) and quantitative information on site-specific (e.g., trap location) characteristics (e.g., topographical features, slope, aspect, climatologic factors) could increase southern flying squirrel capture success. © 2017 The Wildlife Society.

KEY WORDS capture success, *Glaucomys volans*, habitat, modified trap design, Sherman trap, southern flying squirrel.

Wildlife research often includes capturing and handling individual animals. Wildlife can be difficult to monitor; therefore, animal capture for marking with radiotransmitters is essential to determine home range use, seasonal movements, survival, cause-specific mortality, habitat use, and disease prevalence (Fridell and Litvaitis 1991, Conner 2001, Taulman and Smith 2004, McCleery et al. 2008, Prince et al. 2014). Modern advances in capture techniques and handling methods have minimized the risk of mortality and stress imposed on individual animals at the time of capture (Koprowski 2002, Fowler 2011, Sikes et al. 2016). These advances have become increasingly important because of the expense and logistics of animal capture and increased public awareness and sensitivity to animal welfare issues (Kock et al. 1987, Moehrenschlager et al. 2003, Jacques et al. 2009).

Numerous studies have demonstrated that no single trapping method can yield accurate and unbiased estimates of abundance and community structure of small mammal populations (Weiner and Smith 1972, Boonstra and Rodd 1982, Williams and Braun 1983, Anthony et al. 2005). Different trap types have inherent biases and mechanical limitations that may favor disproportionate capture of some species, sex, and age classes over others (Anthony et al. 2005, Umetsu et al. 2006, Dizney et al. 2008, Stephens and Anderson 2014). Nevertheless, Sherman traps are the most commonly used live traps in studies of small mammals (Slade et al. 1993), and have been successfully used in the capture of

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arboreal species such as the southern flying squirrel (*Glaucomys volans*; Engel et al. 1992, Risch and Brady 1996, Loeb et al. 1999, Laves and Loeb 2006). Southern flying squirrels spend proportionately less time foraging on the ground than in trees (Sonenshine et al. 1979). Previous investigations have reported low capture rates of southern flying squirrels using ground traps. For instance, Golley et al. (1965) reported that no southern flying squirrels were captured during a 12-year ground-level trapping study (86,000 trap-nights) at the Savannah River Site in west-central South Carolina, USA. Sawyer and Rose (1985) abandoned southern flying squirrel trapping at ground level because of low capture rates (i.e., 1 captured in 528 trap-nights). Furthermore, Risch and Brady (1996) evaluated potential effects of trap height on capture success of southern flying squirrels, although they did not include ground traps in their study because of low capture success reported in previous studies. Consequently, limited time spent on the ground by southern flying squirrels necessitates above-ground trapping methods and modifications of capture protocols. Previous study designs have evaluated capture success as a function of varying height above ground, though results are conflicting. For instance, Risch and Brady (1996) suggested that traps at the lowest height (2 m) were the least effective in capturing southern flying squirrels. However, Engel et al. (1992) found no difference in southern flying squirrel capture success between traps placed <3.1 m and >3.1 m above ground. Sonenshine et al. (1979) reportedly captured southern flying squirrels in traps placed at 2.4 m above ground. Nevertheless, the lack of standardization in trapping height coupled with variation in capture rates reported in most studies makes assessing the effectiveness of different trapping heights difficult (Risch and Brady 1996). Furthermore, previous study designs have been limited to permanently affixing Sherman traps above ground (i.e., in trees), which may contribute to more labor-intensive set-up, daily monitoring of traps for captured individuals, and (depending on height above ground) greater risk of injury to field personnel during set-up, take-down, and redeployment of traps. Thus, development of a portable Sherman trap design may ameliorate potential logistical and safety constraints associated with use of permanent trap designs.

Validating assumptions underlying the utility of live-trapping data contributes to effective mammalian conservation and management and may relate directly to time-dependent (e.g., weather) and time-independent (e.g., habitat) factors that likely influence trap success (Perry et al. 1977). Previous investigations have identified the relative importance of environmental conditions on capture success of various terrestrial mammals (Mystkowska and Sidorowicz 1961, Gentry et al. 1966, Bailey 1969, Chapman and Trethewey 1972), including other North American tree squirrels (Perry et al. 1977). Nevertheless, quantitative estimates of the magnitude of factors affecting capture success of flying squirrel populations have focused solely on the effects of trapping methodologies (Engel et al. 1992, Risch and Brady 1996, Taylor and Lowman 1996, Loeb et al. 1999, Laves and Loeb 2006). Because of the unique landscape characteristics (i.e., substantial forest fragmentation) across the Midwestern United States, capture success of ground-dwelling small mammals may vary as a function of heterogeneity in time-dependent and time-independent factors relative to geographic regions characterized by more contiguous forests (Getz 1961, Gentry et al. 1966); such also may be the case for southern flying squirrels. Thus, our objectives were to 1) develop and evaluate the efficacy of a portable Sherman trap design for capturing southern flying squirrels and 2) quantify the magnitude of time-dependent (e.g., weather) and time-independent (e.g., habitat, extrinsic, sex) factors on capture success of southern flying squirrels in fragmented forests across the Midwest.

STUDY AREA

Our study was conducted in a 2,108-km^2 area of west-central Illinois, USA (e.g., Hancock County). Landscape characteristics consisted primarily of flat upland prairies fringed by bluffs and valleys near the Illinois and Mississippi River watersheds with elevation ranging from 145 m to 213 m (Walker 2001). Additionally, average summer and winter temperatures were 22.9° C and −3.4° C, respectively (Walker 2001). Total annual precipitation and seasonal snowfall across Hancock County averaged 97.7 cm and 62.5 cm, respectively (Walker 2001).

We conducted our study at the Alice L. Kibbe Field Station (hereafter, Kibbe Station), a 0.9-km^2 area surrounded by 4-km^2 of land owned by the Illinois Department of Natural Resources along the Mississippi River. Site-specific landscape characteristics ranged from sandbars, islands, intermittent creeks, limestone cliffs, hill prairies, floodplain forests along the Mississippi River shoreline, and mature secondary oak (*Quercus* spp.) woodlands (Schwegman et al. 1973). Dominant overstory woody vegetation at xeric sites included white oak (*Q. alba*), post oak (*Q. stellata*), black oak (*Q. velutina*), and mockernut hickory (*Carya tomentosa*); whereas, mesic sites were dominated by white oak, northern red oak (*Q. rubra*), shagbark hickory (*C. ovata*), bitternut hickory (*C. cordiformis*), white ash (*Fraxinus americana*), sugar maple (*Acer saccharum*), American basswood (*Tilia americana*), American elm (*Ulmus americana*), and black cherry (*Prunus serotina*). Dominant understory vegetation in open oak woodland communities included pointed-leaved tick trefoil (*Desmodium glutinosum*), elmleaf goldenrod (*Solidago ulmifolia*), white snakeroot (*Ageratina altissima*), clustered black snakeroot (*Sanicula odorata*), nodding fescue (*Festuca subverticillata*), Pennsylvania sedge (*Carex pensylvanica*), ironwood (*Ostrya virginiana*), and roughleaf dogwood (*Cornus drummondii*).

METHODS

Trap Design

Our trap design consisted of modifying a standard (7.62 cm × 9.53 cm × 30.48 cm) Sherman trap (H. B. Sherman Traps, Inc., Tallahassee, FL, USA; hereafter, modified Sherman trap) by drilling 2 sets of 2 holes approximately 3.5 cm from the outer edge and 1 cm from the ends of each trap and attaching standard 18-gauge soft wire through each set of holes, which served as points of attachment for tow ropes (e.g., bailing twine; Fig. 1). We secured soft wire on the outside of traps to minimize potential injury to captured animals. We positioned modified Sherman traps flush against a 38-cm-long wood platform (5.1 cm × 10.2 cm × 38.1 cm; hereafter, trap base) attached to a tree using 2 13-cm nails (Fig. 2). We drilled 2 0.64-cm sets of nail holes along the outer edges of trap bases positioned approximately 8 and 13 cm from either end (Fig. 2); multiple nail holes accommodated variation in tree size and maximized the likelihood of providing stability when attaching trap bases. We drilled 2 additional 0.64-cm holes along the top surface of trap bases positioned approximately 4.0 cm from the outer edge and 3.5 cm from each end; these holes facilitated attachment of tow ropes to trap bases and subsequent raising and lowering of traps during trapping activities (Fig. 2). Lastly, we mounted 2 lag screw eyes (0.5 cm × 3.0 cm; Manufacturer Express, Inc., Wood Ridge, NJ, USA) along the outer edges of trap bases positioned approximately 3.5 cm from each end (Fig. 2), which minimized the likelihood of entanglement of tow ropes when raising and lowering higher elevation (≥6 m) traps. We used 1.8-m wood step ladders (Babcock Company, Inc., Kinston, NC, USA) or climbing tree stands (API Outdoors, Windom, MN, USA) to mount and remove trap bases from trees. Additionally, we attached a third tow rope directly to traps (Fig. 2) placed at higher elevations (e.g., ≥6 m) to ensure that suspended traps could be lowered from trap bases without obstruction; tow ropes

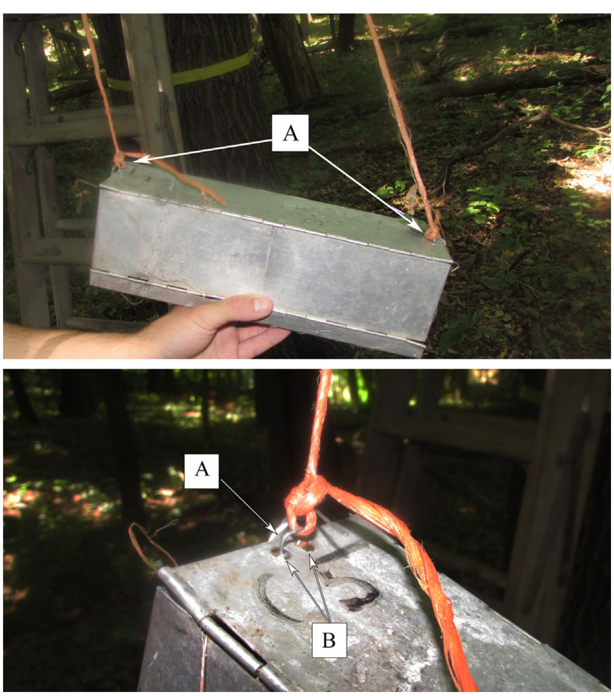

Figure 1. Top panel: View of soft wire attachment points (A) for tow ropes at ends of modified Sherman trap design for capturing southern flying squirrels during summer 2015–2016 at the Alice L. Kibbe Field Station, Illinois, USA. Bottom panel: soft wire was fastened through holes drilled above trap doors (B) on either end of the modified Sherman trap design for capturing southern flying squirrels during summer 2015–2016 at the Alice L. Kibbe Field Station, Illinois, USA.

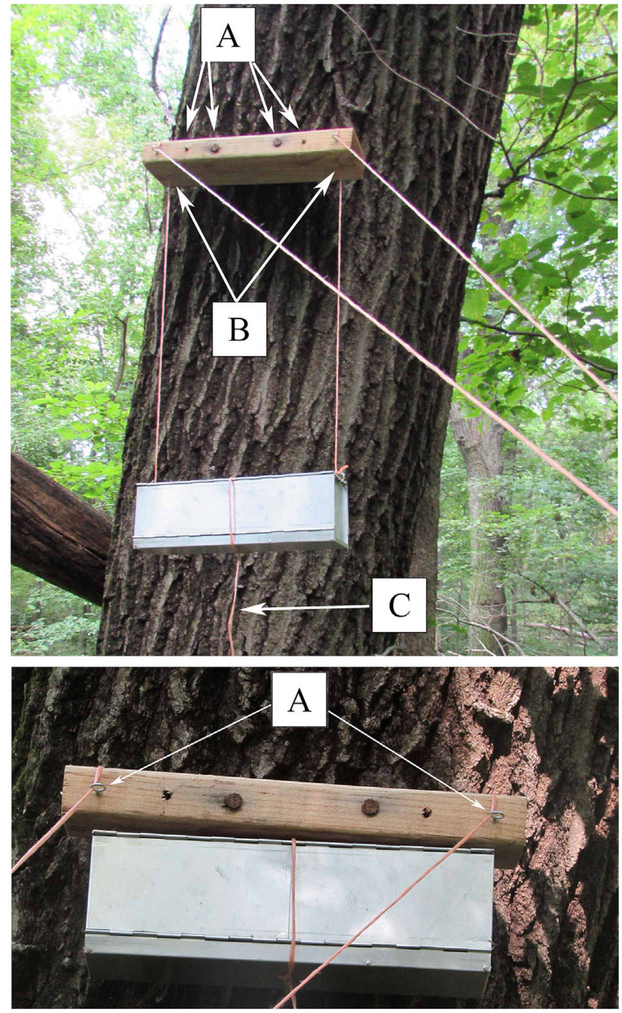

Figure 2. Top panel: View of modified Sherman trap design for capturing southern flying squirrels during summer 2015–2016 at the Alice L. Kibbe Field Station, Illinois, USA, including trap base attached to tree using nails placed in 2 of 4 predrilled holes (A), attachment of tow ropes through predrilled holes, (B) and a third tow rope (C) attached directly to trap to facilitate raising and lowering from trap base during trapping activities. Bottom panel: View of modified Sherman trap design for capturing southern flying squirrels, including a close-up view of predrilled nail holes on trap base mounted to tree, final placement of Sherman trap flush against the trap base, and threading of tow ropes through lag screw eyes (A) placed on outer edges of trap bases.

should be approximately twice the length of the above-ground level of traps. We raised traps until flush against trap bases (Fig. 2) and secured traps by fastening tow ropes to nearby branches or trees (Fig. 3).

Flying Squirrel Capture and Handling

We used modified Sherman traps ($n = 120$) baited with a peanut butter, oats, and bacon grease mixture (Weigl and Osgood 1974) and systematically placed them every 15 m along 4 450-m transects (i.e., 30 traps/transect placed at 0, 3, or 6 m above ground) to capture southern flying squirrels during summer (May–Aug) 2015 and 2016. We selected above-ground trap heights that were within the range of trap heights previously evaluated by Risch and Brady (1996). Further, our 3-m trap height facilitated rapid trap

Figure 3. Overview of modified Sherman trap design actively trapping southern flying squirrels during summer 2015–2016 at the Alice L. Kibbe Field Station, Illinois, USA, including suspension of trap above ground by securing tow ropes to anchor points (e.g., nearby vegetation).

deployment using step ladders, whereas 6 m above ground represented the maximum height of most (>75%) trees suitable (e.g., straight and branch free) for climbing tree stands. Due to the communal nesting habits of southern flying squirrels during winter months (Layne and Raymond 1994), we limited our trapping activities to summer months to avoid exposing animals to unfavorable weather conditions, and thus decreased capture mortality. We used stratified random sampling to maximize the probability that trapping efforts were conducted throughout multiple vegetation types (e.g., mature mesic oak woodlands, xeric oak woodlands, floodplains). Further, we opportunistically selected transect starting locations and orientation as needed based on suitability of trees (e.g., straight and branch-free for ≥6 m) for climbing or to ensure that transects were consistently placed within specific vegetation types rather than intersecting multiple vegetation types. We conducted trapping efforts simultaneously across each location for 7–10 trap days, after which time we redeployed traps to new areas where trapping had not been conducted previously. To minimize potential confounding effects of trap height on orientation, we alternated trap orientation between above-ground trap heights within and across all transects. We repeated this trapping effort and interval throughout the trapping season to maximize capture success. We checked all traps daily between 0600 and 0900 hours to minimize time in traps and potential loss of body mass (Kaufman and Kaufman 1994, Powell and Proulx 2003). Following capture events, we closed traps during daylight hours (0900–1700 hours) and adverse environmental conditions (e.g., ambient temp ≤15° C or ≥32° C, thunderstorms) to further minimize stress or capture-related mortality events on flying squirrels or nontarget species. We reopened traps during late afternoon (1800–2000 hours) and resumed capture efforts the following morning of each day.

After capture, we anesthetized adult flying squirrels in a sealed plastic container using 3 mL of isoflurane injected into a cotton ball soaked in mineral oil (Steinhoff et al. 2012). We fitted adult (≥55 g; Sollberger 1943) animals with radiocollars (collar wt = 4.2 g, ≤7% total body mass; 165 MHz, model M1540; Advanced Telemetry Systems, Isanti, MN, USA) and recorded body mass, sex, age (juvenile or adult), and reproductive condition of all captured individuals (Wells-Gosling 1985, Taulman et al. 1998). Additionally, we fitted all squirrels with 2 metal ear tags (Number 1; National Band and Tag Company, Newport, KY, USA) prior to release. We recorded all animal capture locations as Universal Transverse Mercator coordinates using a handheld global positioning system (Garmin International Inc., Olathe, KS, USA). We considered capture of new individuals or recapture of previously marked individuals a successful capture event. Conversely, traps that did not capture or recapture flying squirrels were considered unsuccessful capture events. We compiled the total number of flying squirrel capture and noncapture events prior to analyses. Our animal handling methods were approved by the Institutional Animal Care and Use Committee at Western Illinois University (approval number 15-01) and followed guidelines for the care and use of animals approved by the American Society of Mammalogists (Sikes et al. 2016).

Data Analyses

Prior to analyses, we posited biologically plausible logistic regression models of how flying squirrel trap success might be influenced by extrinsic (trap orientation [TO], no. of trap-nights [TN]) and habitat (diameter at breast height [DBH] of trees containing traps, distance to nearest mast tree [MTD], burn history [frequent, moderate, infrequent, no burn; BHIST) factors (Table 1). Additionally, we used Poisson regression to determine potential effects of weather (maximum daily temperature [MAXT], minimum daily temperature [MINT], mean relative humidity [RH], cloud cover [CC], wind speed [WIND]), and precipitation [PRECIP]; Iowa Environmental Mesonet 2016; weather station: Keokuk Lock and Dam 19) factors (Table 1) on capture success with an offset of the logarithm of the total

Table 1. Final variables used to evaluate potential weather, habitat, and intrinsic effects on southern flying squirrel capture success during summer at the Alice L. Kibbe Field Station, Illinois, USA, 2015–2016.

Variable name	Description
Maximum temperature	Daily max. temp (°C; MAXT; ranged between 11.7° C and 33.9° C)
Minimum temperature	Daily min. temp (°C; MINT; ranged between 5.0° C and 22.8° C)
Relative humidity	Mean daily relative humidity (%; RH)
Cloud cover	Daily cloud cover (%; CC)
Wind	Average daily wind speed (mph; WIND)
Precipitation	Total daily precipitation (cm; PRECIP)
Burn history	Site-specific burn prescriptions included infrequent (i.e., prescription burn every 15 yr), moderate (i.e., 2 prescription burns every 15 yr), frequent (i.e., 3–5 prescription burns every 15 yr), and no burn (i.e., sites characterized by no prescription burning; BHIST)
Diameter at breast height	Diam at breast ht of trees containing squirrel traps (cm; DBH)
Mast tree distance	Distance of trap locations to nearest mast tree (m; MTD)
Trap orientation	Relative trap location (i.e., ground vs. in tree [northeast vs. southwest side]; TO)
Trap-nights	Total no. of nights required to capture a squirrel (TN)

number of traps available for capture per night. We censored all traps that captured nontarget species from our analyses. We did not quantify DBH or MTD during the 2015 capture season, so we limited our analyses of extrinsic and habitat factors on capture success to data collected during the 2016 capture season. We used Akaike's Information Criterion (AIC) to rank models that best described these data and used Akaike weights (w_i) as a measure of relative support for model fit (Burnham and Anderson 2002, Jacques et al. 2011). We considered models differing by $\geq$2 ΔAIC from the highest-ranked model as noncompetitive and thus excluded them from further consideration (Burnham and Anderson 2002).

Prior to modeling, we screened all predictor variables for collinearity using Pearson's correlation coefficient ($|r| > 0.5$) and used quantile plots to evaluate assumptions of normality; we used only 1 variable from a set of collinear variables for modeling (Jacques et al. 2011). We determined predictive capabilities of models with area under the receiver operating characteristic (ROC) curve; we considered ROC values between 0.7 and 0.8 acceptable discrimination and values $\geq$0.8 excellent discrimination (Hosmer and Lemeshow 2000, Jacques et al. 2011). We considered ROC values from 0.5 to 0.7 to indicate low discrimination, and values $\leq$0.5 to indicate that model predictive capabilities were no better than random (Grzybowski and Younger 1997, Hosmer and Lemeshow 2000). We used chi-square (χ^2) analyses to test for differences in capture success between squirrel sex classes. We used Bonferroni correction factors to maintain experiment-wide error rates when performing multiple χ^2 analyses (Neu et al. 1974). We conducted Poisson regression modeling using Program R (R Core Team 2015) and all other statistical analyses using SYSTAT (SYSTAT Software, Inc., Richmond, CA, USA; Wilkinson 1990); statistical tests were conducted at $\alpha = 0.05$.

We determined associations between response and predictor variables using odds ratios. The odds ratio for a predictor variable is the relative amount by which the odds of the outcome increase (odds ratio >1.0) or decrease (odds ratio <1.0) with each unit increase in the predictor variable (Hosmer and Lemeshow 2000, Freund and Wilson 2003, Jacques et al. 2011). Thus, odds ratios approximated the likelihood of a predicted outcome among associated variables. The appropriate interpretation of odds ratios obtained from model parameters for continuous (predictor) variables was that multiplicative effects on the odds of a 1-unit increase in the response variable was associated with fixed levels of other predictor variables (Hosmer and Lemeshow 2000, Freund and Wilson 2003, Jacques et al. 2011).

RESULTS

We captured 82 (48 F, 32 M, 2 unknown) southern flying squirrels 165 times during 9,795 trap-nights. Mean number of individuals captured/120 trap-nights was 1.24 (SE = 0.12), which ranged from 0 to 7 animals. Of 165 total capture events, 78 occurred during 2015 and 87 occurred during 2016. The total number of capture events was greater ($\chi^2_1 = 148.39$, $P \leq 0.001$) for traps placed above ground (97.6%; $n = 161$) than those placed at ground level (2.4%; $n = 4$), though capture success was similar ($\chi^2_1 = 0.40$, $P = 0.53$) between traps placed at 3 m ($n = 77$) and 6 m ($n = 84$) above ground. Similarly, capture success was greater ($\chi^2_1 = 33.80$, $P \leq 0.001$) for female ($n = 119$) than male ($n = 44$) squirrels.

Predicting Southern Flying Squirrel Capture Success

The highest-ranked model for predicting effects of climatological factors on capture success of southern flying squirrels was MAXT + MINT + RH + WIND + CC + PRECIP (Table 2); weight of evidence (w_i) supporting this model was 0.73. Further, the weight of evidence supporting the highest-ranked model was 3.8 times greater than the MINT + WIND model ($w_i = 0.11$), 5.3 times greater than the MINT + PRECIP model ($w_i = 0.05$), and 5.5 times greater than the MINT + CC model ($w_i = 0.05$; Table 2). The logistic equation for the highest-ranked model was logit (μ: no. of squirrels captured/total no. of traps available for capture per night) = −2.556 − 0.105(MAXT) + 0.183(MINT) − 0.015(RH) − 0.090(WIND) − 0.005 (WIND) + 0.013(PRECIP). The 95% confidence intervals for parameter estimates of the MAXT (95% CI = −0.174 to −0.036), MINT (95% CI = 0.267–0.395), and WIND (95% CI = −0.164 to −0.017) covariates did not overlap zero and

Table 2. Akaike's Information Criterion model selection of *a priori* Poisson regression models for evaluating potential effects of weather variables on capture success of southern flying squirrels during summer at the Alice L. Kibbe Field Station, Illinois, USA, 2015–2016; all capture success models were estimated using 165 capture events.

Model covariates[a]	K[b]	AIC$_c$[c]	ΔAIC$_c$[d]	w_i[e]
MAXT + MINT + RH + WIND + CC + PRECIP	7	351.89	0.00	0.73
MINT + WIND	3	355.73	3.84	0.11
MINT + PRECIP	3	357.21	5.32	0.05
MINT + CC	3	357.37	5.48	0.05
MINT	2	357.38	5.49	0.05
MINT + RH	3	359.14	7.25	0.02
PRECIIP + WIND	3	366.30	14.41	0.00
CC	2	368.53	16.64	0.00
MAXT + RH	3	369.84	17.95	0.00
INTERCEPT-ONLY	1	369.85	17.96	0.00
RH	2	371.91	20.02	0.00

[a] MAXT = daily maximum temperature (°C); MINT = daily minimum temperature (°C); RH = mean relative humidity (%); WIND = daily wind speed (mph); CC = daily cloud cover (%); PRECIP = daily precipitation (cm); INTERCEPT-ONLY = model consisting of the intercept term only, serving as a null model for model comparisons.
[b] Number of parameters.
[c] Akaike's Information Criterion adjust for small sample sizes (Burnham and Anderson 2002).
[d] Difference in AIC$_c$ relative to minimum AIC$_c$.
[e] Akaike weights (Burnham and Anderson 2002).

P-values were significant ($P \leq 0.016$), indicating these variables were influential predictors of flying squirrel capture success. In contrast, 95% confidence intervals for parameter estimates of the RH (95% CI = −0.037 to 0.007), CC (95% CI = −0.010 to 0.001), and PRECIP (95% CI = −0.004 to 0.030) covariates overlapped zero and P-values were not significant ($P \geq 0.10$), indicating these variables were not statistically important predictors of flying squirrel capture success. Probability of capture success decreased 0.10 (odds ratio = 0.90, 95% CI = 0.89–0.91)/1° C increase in daily maximum temperature and by 0.09 (odds ratio = 0.91, 95% CI = 0.91–0.92)/unit increase (km/hr) in wind speed (Table 3). Conversely, probability of capture success increased by 1.2 (odds ratio = 1.20, 95% CI = 1.19–1.22)/1° C increase in daily minimum temperature (Table 3). Optimal maximum and minimum temperature ranges over which most (74%) southern flying squirrel capture events occurred were 24–32° C and 16–22° C, respectively.

The highest-ranked model for predicting effects of habitat and extrinsic factors on capture success of southern flying squirrels was TO (Table 4). Support for this model was substantial (w_i = 0.997), though predictive capability was low (ROC = 0.66). For model TO, β and 95% confidence intervals for the intercept (−3.396, SE = 0.159, 95% CI = −3.707 to −3.085), TO_ground (−2.824, SE = 0.725, 95% CI = −4.246 to −1.403), and TO_southwest (−0.382, SE = 0.169, 95% CI = −0.713 to −0.051) covariates did not overlap zero and P-values were significant ($P \leq 0.001$), indicating that trap orientation was an influential predictor of flying squirrel capture success. Probability of capturing flying squirrels declined 0.94 (odds ratio = 0.059, 95% CI = 0.014–0.246) and 0.32 (odds ratio = 0.682, 95% CI = 0.382–0.982) on the ground and on traps positioned on the southwest side of a tree, respectively (reference category = TO_northeast [traps positioned on northeast side of tree]).

Table 3. Parameter estimates (β), standard error (SE), odds ratio, and odds ratio 95% confidence intervals for the best approximating Poisson regression model for evaluating effects of climatologic factors on southern flying squirrel capture success during summer at the Alice L. Kibbe Field Station, Illinois, USA, 2015–2016.

Parameter[a]	β	SE	Odds ratio[b]	Upper CL[c]	Lower CL[c]
Intercept	−2.556	1.122			
MAXT	−0.105	0.035	0.90	0.91	0.89
MINT	0.183	0.043	1.20	1.22	1.19
RH	−0.015	0.011	0.99	1.01	0.95
WIND	−0.090	0.037	0.91	0.91	0.92
CC	−0.005	0.003	0.99	1.00	0.98
PRECIP	0.013	0.009	1.01	1.04	0.99

[a] MAXT = daily maximum temperature (°C); MINT = daily minimum temperature (°C); RH = mean relative humidity (%); WIND = daily wind speed (mph); CC = daily cloud cover (%); PRECIP = daily precipitation (cm); an unsuccessful capture event was the reference category.
[b] Odds ratios used to estimate measures of association between variables. A measure of association in which a value near 1 indicates no relationship between variables (Hosmer and Lemeshow 2000).
[c] Upper and lower 95% confidence intervals.

DISCUSSION

A notable difference in our trap design compared with traditional Sherman trap designs is the portability associated

Table 4. Akaike's Information Criterion model selection of *a priori* Poisson regression models for evaluating potential effects of habitat and intrinsic factors on capture success of southern flying squirrels during summer at the Alice L. Kibbe Field Station, Illinois, USA, 2015–2016. MTD and DBH were not quantified during 2015; thus, all capture success models were estimated using 2016 (n = 125) capture events.

Model covariates[a]	K[b]	AIC$_c$[c]	ΔAIC[d]	w_i[e]
TO	3	703.30	0.00	0.997
BHIST + TN + TO + DBH + TS + MTD	10	714.30	11.68	0.003
DBH	2	721.07	17.77	0.000
DBH + MTD	3	722.65	19.35	0.000
TS + DBH	3	722.82	19.52	0.000
BHIST	4	724.69	21.39	0.000
TS + MTD	3	735.09	31.79	0.000
TN	2	735.36	32.06	0.000
INTERCEPT-ONLY	1	735.46	32.17	0.000

[a] TO = relative trap location (i.e., ground vs. in tree [northeast vs. southwest side]); BHIST = site-specific burn history prescriptions included infrequent (i.e., prescription burn every 15 yr), moderate (i.e., 2 prescription burns every 15 yr), frequent (i.e., 3–5 prescription burns every 15 yr), and no burn (i.e., sites characterized by no prescription burning); TN = total number of nights required to capture a squirrel; DBH = diameter at breast height of trees containing squirrel traps; TS = tree species (hard mast vs. soft mass); MTD = distance of trap locations to nearest mast tree; INTERCEPT-ONLY = model consisting of the intercept term only, serving as a null model for model comparisons.
[b] Number of parameters.
[c] Akaike's Information Criterion adjusted for small sample sizes.
[d] Differences in AIC$_c$ relative to minimum AIC$_c$.
[e] Akaike weights (Burnham and Anderson 2002).

with raising and lowering traps from a permanent trap base. Traps were mounted flush against trap bases and secured using tow ropes; therefore, we did not need to permanently affix them to trees. The portability of our trap design reduced set-up time (i.e., mounting trap base) to <10 min and trap monitoring (i.e., checking for closed trap doors) to <1 min. Reduced set-up time better enables researchers to move traps that are not productive or those that have previously captured squirrels, thereby facilitating more efficient spatial distribution of radiomarked individuals or capture success across study areas. Total cost per trap was US$28.10, with much of the cost allocated to purchasing Sherman traps (US$25.59 each). Reduced costs and portability of our modified trap design relative to previous trap designs enabled field crew members to be more flexible with trap redeployment out of areas where recapture events were common. Although our study was not designed to compare overall time savings associated with trap set-up, monitoring, and handling target and nontarget species between portable and permanently affixed Sherman trap designs, field crew members spent approximately 3 min navigating between traps, releasing nontarget species, and rebaiting traps using our trap design. Although uncertain, we estimate that a minimum of 10 min/trap would be required to navigate between trap locations, check (i.e., detach and reattach) traps, release bycatch, and rebait using permanently affixed trap designs. Conservatively, we estimate that use of our trap design may be 300% more time-efficient than permanent Sherman trap designs.

We evaluated the efficacy of our trap design by recording 165 total capture events using fewer than 3 field crew members/year, most of whom had no previous experience with small mammal trapping equipment or capturing squirrels. Minimal mortality (1.8% of total capture events) and multiple recapture events (50.3% of total capture events) indicate that our trap design was a safe method for capturing flying squirrels with potential to effectively target the adult female segment of the population. Similarities in capture success as a function of trap height yielded results consistent with previous studies (Risch and Brady 1996, Loeb et al. 1999) and confirmed the importance of placing traps above ground to facilitate successful flying squirrel capture. However, our results do not support previous results by Risch and Brady (1996), who noted that animals captured multiple times tended to be captured at a single trap height more often than expected. Instead, our results support the hypothesis postulated by Engel et al. (1992) that southern flying squirrels are equally likely to be captured at varying heights above ground; we recorded 77 and 84 capture/recapture events at 3 and 6 m above ground, respectively. Further, we recaptured 6 times greater numbers of female than male squirrels, which may reflect increased energy demands of lactation and rearing young during the breeding season (Fridell and Litvaitis 1991, Raymond and Layne 1988).

Flying squirrel capture success was best described by predictive models containing maximum and minimum temperature, wind speed, and trap orientation. Strong associations between capture success and weather factors were not surprising and make biological sense given the ecology and life history characteristics of southern flying squirrels. Flying squirrels are small-bodied mammals that remain active and euthermic throughout the year (Dolan and Carter 1977, Bowman et al. 2005), which should make them sensitive to seasonal variation in temperature and precipitation. Southern flying squirrels have developed a number of strategies to minimize expenditure of energy for maintaining body temperature, which occur during winter (e.g., communal nesting, seasonal thermogenesis) months (Stapp et al. 1991, Merritt et al. 2001). Energetic costs on flying squirrels also likely occur during summer months (May–Aug). We documented negative relationships between capture success and maximum daily temperature and average daily wind speed. Conversely, capture success was positively associated with increasing minimum daily temperatures. Our results partially support previous investigations of tree squirrels that noted negative relationships between capture success and ambient temperature and effects of wind speed on initiation and duration of daily movements (Weigl and Osgood 1974, Perry et al. 1977). Similarly, our results are consistent with previous studies noting inverse relationships between maximum daily temperatures and capture success of small mammals (*Microtus* spp.; Getz 1961) and cottontail rabbits (*Sylvilagus floridanus*; Chapman and Trethewey 1972). The importance of these factors likely reflects thermoregulatory constraints imposed on small body sizes and the need to alter activity patterns to efficiently thermoregulate on a seasonal basis (Barbault 1988, Stapp 1992). Our results indicated that small deviations in daily maximum and minimum temperatures had notably different effects on summer capture success, whereby the number of animals captured was positively associated with increasing daily minimum temperatures yet negatively associated with increasing daily maximum temperatures. Similarly, capture success decreased with increasing wind speed. Though uncertain, it is possible that daily variation in these weather factors may have affected animal movements and thus contributed to a relatively narrow range of ambient temperatures (16–30° C) and wind speeds (0–11 km/hr) over which most (≥82%) squirrel capture events occurred.

The relationship between capture success and trap orientation revealed by our analysis may be related to behavioral mechanisms used by flying squirrels to balance acquisition of resources (e.g., food) against thermoneutrality (Weigl and Osgood 1974, Stapp 1992). For instance, trap surface temperatures may have been greater for southwest-facing traps and as such, flying squirrels may have had a greater propensity for traps placed on the northeast side of the tree because of the cooler surface temperatures. Further, we documented limited capture-related deaths ($n = 3$), in which case each individual was captured in traps positioned on the southwest side of the tree and was found dead or near death the next morning following failed attempts to escape (i.e., partly exposed bodies visible during routine trap monitoring). We assumed that hot trap surfaces or elevated temperatures inside closed traps prompted increased efforts by individuals to escape. Our results are important because, to our knowledge, few studies have presented empirical data quantifying the relative magnitude of potential weather and habitat effects on flying squirrel capture success. Thus, our results may be of particular interest to wildlife managers given fragmentation across Midwestern landscapes (Rosenblatt et al. 1999) and predicted increases in global surface temperatures (and thus potential for greater capture-related mortality and reduced capture success using Sherman traps) over the next 50–100 years (Intergovernmental Panel on Climate Change 2001).

MANAGEMENT IMPLICATIONS

We provide the first evaluation of potential effects of ecologic factors on capture success of southern flying squirrels in Midwestern landscapes. When tree-mounted traps are required, we show that our modified trap design is a safe, efficient, and cost-effective method of capturing animals when moderate weather (temp and wind speed) conditions prevail. Nevertheless, deploying perforated-style Sherman traps, shutting down trapping efforts when ambient temperatures exceed 30° C, and monitoring traps more frequently (e.g., every 4 hr) throughout nightly trapping intervals may further reduce capture-related mortalities. Future use of our trap design may provide researchers with an alternative option for targeting reproductively active females during the mating season. Additionally, strategic placement of traps (e.g., northeast side of tree, 3 m above ground) could increase southern flying squirrel capture success.

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