Distribution and Seasonal and Diurnal Activity Patterns of *Eutrombicula alfreddugesi* (Acari: Trombiculidae) in a Forest Edge Ecosystem

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ABSTRACT Microclimatic and vegetative effects on the population size and activity patterns of larval *Eutrombicula alfreddugesi* Oudemans, 1910 (Acari: Trombiculidae), were investigated in Nebraska between latitude 40°0′0″ N and 40°1′21″ N. Larval population densities along a forest edge were greatest in areas of high relative humidity, moderate temperature, low incident sunlight, and increasing substrate vegetation. Although chigger populations existed throughout the forest edge, larger populations concentrated in short- to tall-grass transition zones. Chiggers were rarely found in the undergrowth beneath the tree canopy. Chigger activity correlated with a microclimatically driven diurnal rhythm. Activity was greatest during the late afternoon–early evening, between 1530 and 1930 hours (CDST). Larval activity dropped to low levels and remained so until sunrise; this period of reduced activity occurred between 1930 and 0530 hours. Small increases in larval activity occurred around sunrise (≈0600–0700 hours). Between about 0700 and 1530 hours, larval *E. alfreddugesi* were inactive and did not respond to normal sampling stimuli. Larval populations appeared in late April through early May, peaked in abundance in late June and early July, diminished through late summer, and disappeared in midautumn as the ground began to freeze.

KEY WORDS Trombiculidae, *Eutrombicula alfreddugesi*, ecology

THE CHIGGER MITE *Eutrombicula alfreddugesi* Oudemans, 1910, is a common acarine parasite of humans across much of eastern and central North America, decreasing in abundance above 40°N (Loomis & Wrenn 1984). The parasitic relationship is obligatory but of short duration. In humans, the chigger bite site is marked by a characteristic pruritus and circumscribed inflammatory edema that remains visible for 14–21 d (Jenkins 1948).

Data on vegetation associations and activity responses to abiotic factors of *E. alfreddugesi* are few. Sites that harbored high chigger populations were more closely correlated with vegetative cover than soil type (Wharton & Fuller 1952). Jenkins (1948) broadly described ecological niches that favor the presence of *E. alfreddugesi* to be "transitional areas between forest and grass areas or at swampy borders, forest edge in a shrub area, bramble and blackberry patches." In laboratory studies, larval activity appears to increase as a linear function of temperature between 18 and 38°C at constant relative humidity. High humidity (85%) promoted higher movement rates than low humidity (35%) (Jenkins 1948). Field data indicated that *E. alfreddugesi* populations recovered quickly from major ecological disturbances and may be characteristic of damaged or disturbed ecological communities (Reed et al. 1977).

Our study was conducted to establish the interaction between this chigger species and the environment, as revealed by an analysis of the effects of microclimatic fluctuations on the distribution and diurnal activity patterns of larval *E. alfreddugesi* in several closely related habitats.

Materials and Methods

Research Area. Research was conducted 16 km south of Humboldt, Richardson County, in southeastern Nebraska (40°09′50″ N, 95°56′41″ W). Research sites were established along the northeastern edge of a forest belt that followed a small stream and merged into a short-grass recreational area.

Sampling sites were established in the grassy belt bordering the forest edge. Each sampling site was visually divided into four vegetative zones: mowed grass, ecotone, tall grass, and undergrowth. Buffalo grass and Kentucky bluegrass were the predominant vegetative components of the mowed grass community. Kentucky bluegrass, smooth brome, and switchgrass were the predominant vegetative components of the tall-grass community. The ecotone comprised the interface between mowed and tall grass. Repeated mowing over several years had established the ecotone along a stable line. The undergrowth

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community beneath the forest canopy had little or no understory and comprised small shrubs and saplings, dominated by common chokecherry and sumac.

Distribution. Each sampling site consisted of a segmented belt transect 1 m wide and 3 m deep. Each belt was subdivided into five equal quadrats (20 cm wide, 30 cm deep). Sites were established to place the ecotone line 90 cm from the base of the transect. Three belts of five quadrats each were sampled in the mowed grass and one belt of five quadrats was sampled along the ecotone. The remaining six belts (five quadrats each) were sampled in the tall-grass and undergrowth communities. The number of belts sampled from the tall-grass and undergrowth communities was dependent upon the depth of the tall-grass community. In two sites, the tall-grass community extended beyond the 3-m transect; in these cases, no undergrowth sample was taken. The median depth of each community was as follows: mowed grass, 90 cm; ecotone, 30 cm; tall grass, 120 cm; and undergrowth, 60 cm. Surveys were completed once from each of 11 sites. Samples were taken at the base of each quadrat.

Populations of larval *E. alfreddugesi* were sampled using a modification of the plate sampling method reported by Williams (1946). Sampling plates (Plexiglas squares 10 by 10 by 0.32 cm) were placed on the substrate for ≈1 min and retrieved. Larval chigger mites were counted and aspirated into a vial of 70% EtOH for later recount and identification in the laboratory. Temperature (°C), humidity (%RH), and incident sunlight (watts/m^2) at the soil surface were recorded for each sample point using a CR21 datalogger with independent pyrometer, relative humidity, and thermistor probes.

Preliminary field studies suggested high larval activity between 1730 and 1930 hours (CDST). Samples were collected during this period to provide an accurate measure of relative population densities by reducing the effects of diurnal activity patterns to maximize the capture rate. Distribution samples were taken between 23 June and 2 August 1988. In total, 550 samples were taken from 11 sample sites, yielding 166, 55, 179, and 150 samples from the mowed grass, ecotone, tall-grass, and undergrowth communities, respectively.

The distribution data were analyzed as a correlation matrix using SAS PROC PRINCOMP, providing a principal component analysis solution (SAS Institute 1982).

Seasonal Abundance. Seasonal abundance samples were taken using the modified black-plate method described above. Samples were taken from 16 cleared sites, each roughly circular and 100 m in diameter. Sampling transects were laid across the center of each clearing, and 10 sampling points were staked as follows: two points each in the tall grass and the ecotone on either side of the clearing and two sampling points in the mowed grass near the center of the clearing. Seasonal abundance samples were taken from all 160 sampling points from 5 April, 1988 through 3 January 1989. All samples were taken between 1730 and 1930 hours.

Diurnal Activity Patterns. Three sampling sites (Arapaho, Pawnee, and Ponca) were established (as described above) to study the diurnal activity patterns of larval *E. alfreddugesi*. Arapaho and Pawnee were visually homogeneous and characteristic of the established forest edge community; Ponca was a disturbed area in its second year of regrowth. Poison ivy and switchgrass were the predominant members of the Pawnee tall-grass community.

A single transect in each sampling site was observed for a 24-h period, and 50 data samples were taken at ≈4-h intervals. A single data sample included the following observations: larval count, temperature, relative humidity, and incident sunlight data. Larval counts were made using the modified black-plate method described above. Climatic variables were measured on the soil surface. Data were collected for 3 consecutive d to reduce between-site variation in both space and time. Anecdotal field tests of repeated sampling in a single location indicated minimal population depletion and disturbance under this protocol. In total, 950 samples were taken: 300 samples each from Arapaho and Ponca and 350 samples from Pawnee.

Diurnal activity data were separated into groups by sample plot and vegetative community. Mean surface temperature, relative humidity, incident sunlight, and total larval counts were plotted against a 24-h time line to explore their relationships. Sampling on consecutive days allowed use of a 24-h clock as a convenient standard for experimental comparison, but exact times were expected to vary under seasonal influence.

Results

Distribution. Means for all habitat variables are given in Table 1. These data were useful in gaining a general impression of the character of each vegetative community. Temperature and incident sunlight were high in the mowed grass and dropped rapidly at the ecotone. They remained low through the tall grass and the undergrowth. Relative humidity was low in the mowed grass and increased dramatically at the ecotone, remaining high throughout the tall grass and the undergrowth. Chigger mite population densities were highest at the ecotone and the neighboring 60 cm of tall grass. Figs. 1–4 illustrate average sample climatic and vegetative gradients and chigger population densities over 11 plots sampled.

Table 1. Mean distribution (±SE) of larval *E. alfreddugesi* and niche variable measurements over four vegetative types for 11 sample plots in Richardson County, NE

Variable	Mowed grass	Ecotone	Tall grass	Undergrowth
Temp, °C	34.5 (1.8)	33.8 (1.7)	33.4 (1.5)	33.6 (1.2)
% RH	21.3 (10.2)	23.4 (11.6)	25.6 (12.9)	24.0 (11.8)
Incident sunlight, w/m^2	84.2 (69.0)	47.9 (23.8)	38.7 (27.7)	30.2 (13.3)
Vegetative index[a]	1	2	3	0
Mean no. chiggers per sample	2.9B (4.3)	9.1D (13.2)	5.2C (12.0)	0.6A (1.3)
No. samples (*n*)	166	55	179	150

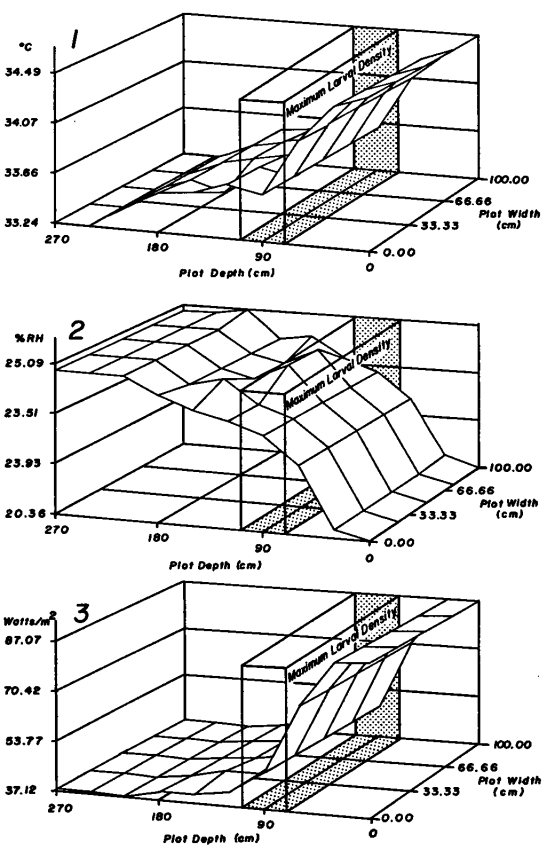
All samples taken between 1700 and 1800 hours (CST), July 1988. Means followed by the same letter are not significantly different under a Protected LSMEANS pair-wise comparison (>0.05); those followed by different letters are statistically different (<0.05).

[a] The vegetative index represents the relative height and density of an area's substrate vegetation: 0 represents a dirt and leaf litter substrate with little ground vegetation; 3 represents densely packed prairie grass with a seasonal height of ≈1.0–1.5 m.

Results from a principal components analysis defined five principal component vectors. The first principal component vector scored an eigenvalue of 2.38 with the following loadings: (0.60 × °C) + (−0.55 × %RH) + (0.66 × (watts/m^2)) + (−0.03 × vegetative index). The second principal component vector scored an eigenvalue of 1.01 with the following loadings: (−0.60 × °C) + (−0.02 × %RH) + (0.01 × (watts/m^2)) + (0.99 × vegetative index). These vectors, respectively, accounted for 60 and 25% of the total variation between chigger mite populations and their associations with habitat variables. They cumulatively accounted for 85% of the total variation and were retained for further analysis. The associated eigenvalues of principal component vectors 3, 4, and 5 were <1.0, indicating that they reflected trivial variation or environmental noise (Jolliffe 1986). These vectors were dropped from the analysis.

The first principal component vector had strong positive loadings for temperature and incident sunlight, a high negative loading for relative humidity, and a low negative loading for substrate vegetation. This vector differentiated habitat upon the basis of climatic features and was called the climatic vector.

The second principal component vector had a high positive loading for substrate vegetation, low positive loadings for temperature and incident sunlight, and a low negative loading for relative humidity. This vector differentiated habitat upon the basis of biotic features and was called the biotic vector.



Figs. 1–3. Average sample climatic and vegetative gradients over 11 plots sampled (50 samples per plot) for larval *E. alfreddugesi* in Richardson County, NE, 23 June–2 August 1988. (1) Substrate surface temperature (°C). (2) Substrate surface relative humidity (%RH). (3) Substrate surface incident sunlight (watts/m^2).

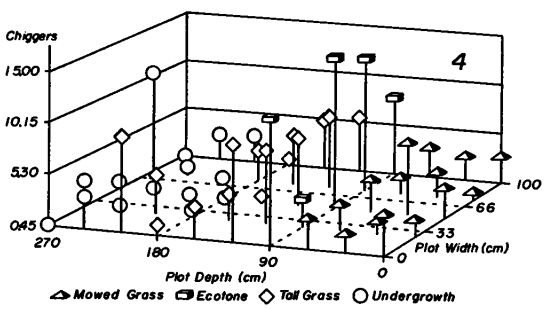


Fig. 4. Pooled sample plot distribution of larval *E. alfreddugesi* in Richardson County, NE, 23 June–2 August 1988 (11 plots sampled; 50 samples per plot). Chigger population density over four vegetative zones: mowed grass, ecotone, tall grass, and forest belt undergrowth.

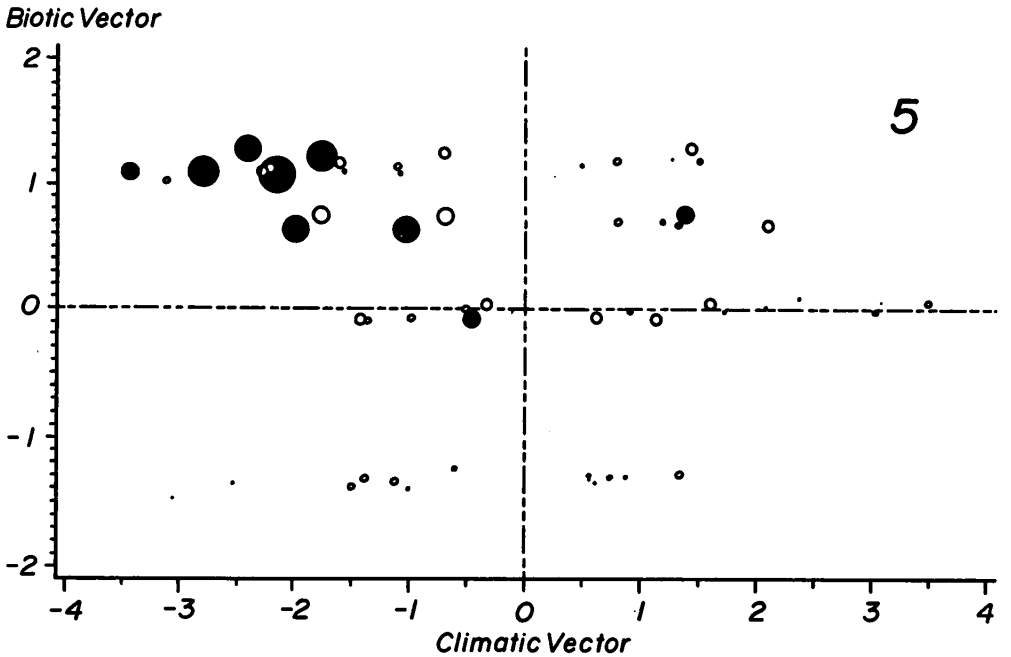


Fig. 5. Pooled sample plot distribution of larval *E. alfreddugesi* in Richardson County, NE, 23 June–2 August 1988 (11 plots sampled; 50 samples per plot). Relative chigger population density plotted against the first two principal component vectors, where: climatic vector = (0.60 × °C) + (−0.55 × %RH) + (0.66 × (watts/m^2)) + (−0.03 × vegetative index); biotic vector = (−0.60 × °C) + (−0.02 × %RH) + (0.01 × (watts/m^2)) + (0.99 × vegetative index). Size of the bubble is proportional to the population density. Densities greater than >10 mites per 0.10 m^2 are darkened.

A plot of larval populations against the first two principal components indicated the relative population density of larval mites through the habitat range studied. Habitat preference became markedly apparent when mite population densities of >10 individuals were shaded (Fig. 5). Habitats that were characterized by high relative humidity, low temperature, low incident sunlight, and an increasing substrate level vegetative canopy typically had high chigger population densities. Habitats that were characterized by low relative humidity, high temperature, high incident sunlight, and a decreasing substrate level vegetative canopy typically had low chigger population densities.

Seasonal Abundance. Fig. 6 depicts the changes in total number of *E. alfreddugesi* larvae recovered per day from 2,560 samples taken 5 April 1988 through 3 January 1989. Although adult specimens of *E. alfreddugesi* were observed in early to mid-April, larvae did not appear until early May. Larval populations rose in abundance to peak in late June and early July. A single chigger was recovered from samples taken on 5 October 1988; however, no chigger was observed through 3 January 1989.

Diurnal Activity Patterns. Plots of mean temperature, relative humidity, incident sunlight, and larval chigger populations over a 24-h period were used to obtain an impression of the diurnal activity patterns of larval *E. alfreddugesi*. Figs. 7–9 present the plots for the tall-grass, ecotone, and mowed grass communities of sample plot Arapaho. Corresponding plots for sample sites Pawnee and Ponca were similar: the Ponca site contained consistently higher population densities than Arapaho and Pawnee; however, there was no difference in diurnal activity pattern. An increase in host density during vegetative regrowth may have contributed to elevated larval densities in the Ponca site. The combined undergrowth communities yielded only seven mites from 150 daily samples and were dropped from the analysis.

Larval activity remained at low levels from ≈1930 to 0530 hours. Small elevations in larval activity occurred at sunrise (0530–0700 hours). Activity dropped to undetectable levels during the midmorning when incident sunlight and temperature increased and relative humidity began to decrease. Activity remained at undetectable levels until sunset, when relative humidity increased and temperatures receded to a tolerable level. During this period of low activity (≈0700–1530 hours), larvae became inactive; they did not respond to normal sampling stimuli. Peak activity occurred during late afternoon–early evening (between 1530 and 1930 hours), after which larval activity decreased as tempera-

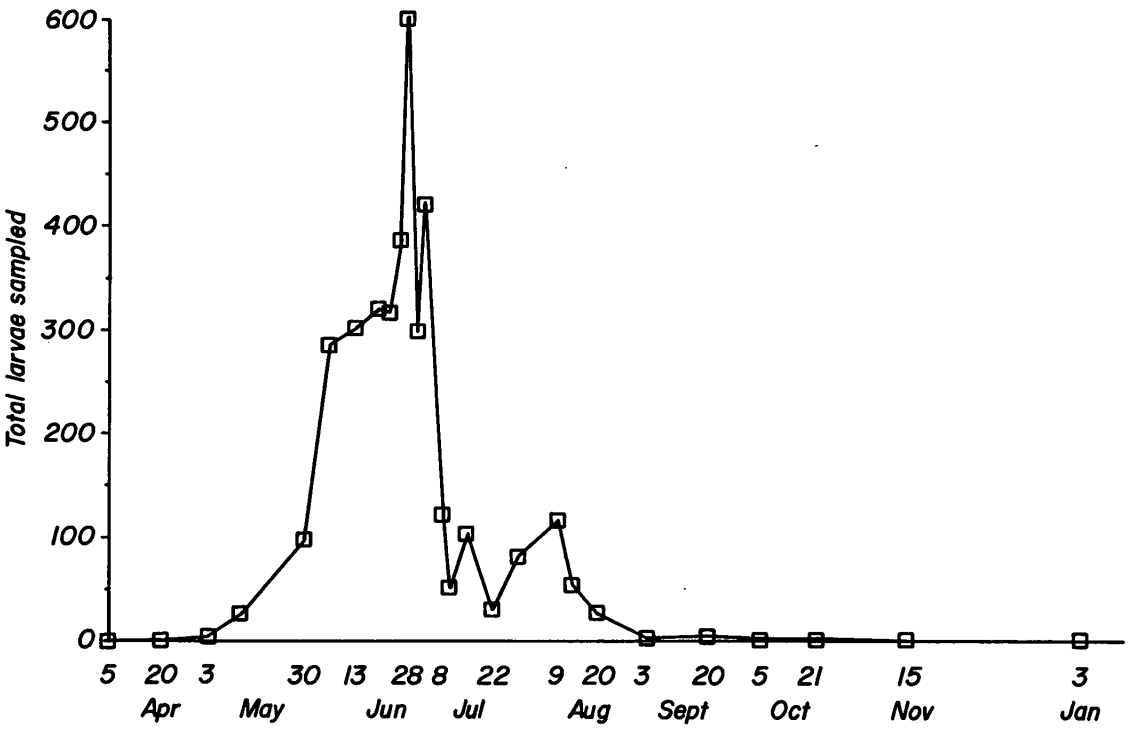


Fig. 6. Seasonal abundance of *E. alfreddugesi*. Total number of larvae recovered per day from 16 sample sites (10 samples per sample site) sampled from April 1988 through January 1989.

tures decreased, reaching a low level several hours after sundown.

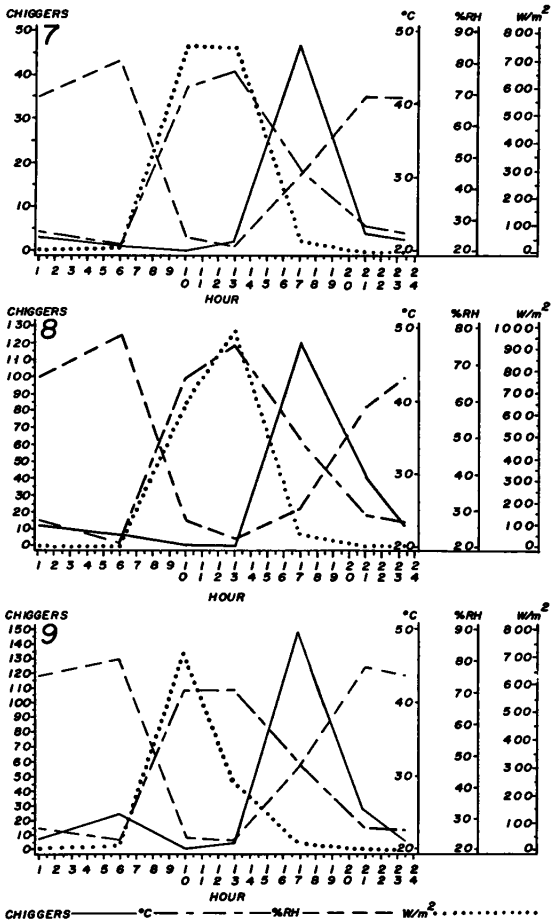
Discussion

Populations of *E. alfreddugesi* larvae appear in late April through early May and rapidly increase in abundance to peak in late June and early July. Populations diminish through late summer and disappear in midautumn as the ground begins to freeze. This unimodal seasonal abundance pattern, coupled with the appearance of adult *E. alfreddugesi* in late March and early April, suggests that these chiggers are univoltine in southeastern Nebraska and probably overwinter as adults.

Eutrombicula alfreddugesi population densities were greatest in areas with high relative humidity, low temperature, low incident sunlight, and a dense substrate vegetative canopy. Their activity levels seem to be limited by high and low temperatures; a combination of high temperature and low relative humidity reduces their activity to undetectable levels. Chiggers survived throughout the forest edge ecosystem; however, principal component analysis indicates the existence of preferred habitat conditions that lead to elevated population densities.

The elevated population density of sample site Ponca suggests that chigger success was enhanced in disturbed areas, perhaps as a function of increased host availability. If the colonizing host populations use small home ranges, this effect should intensify over several years in response to limited parasite emigration and increasing parasite numbers. *E. alfreddugesi* appeared to be univoltine in southeastern Nebraska; however, several seasons of infestation on small rodents should reinforce localized island populations of mites. The work of Reed et al. (1977) indicated that once established, localized populations of *E. alfreddugesi* recovered quickly from subsequent disturbance. Future studies should focus on the formation, growth, and stability of island populations of mites in disturbed areas.

This work extends the work of Jenkins (1948) and Wharton & Fuller (1952) by measuring substrate microclimatic variables and vegetation types and correlating their effects on mite population densities. The hours of peak larval activity were defined by a combination of temperature, relative humidity, and incident sunlight rather than by temperature alone. Larval activity was marked by dawn and late afternoon–early evening activity peaks and a midday reduction in activity. Activity was present throughout the night at low levels. Population sampling or control protocols should be timed to correspond with dawn or late afternoon–early evening peaks to maximize efficiency and effect. The information presented has a temporal resolution of 4 h.



Figs. 7–9. Mean temperature, relative humidity, incident sunlight, and larval *E. alfreddugesi* population density trends over 24 h (CDST) in three microhabitats from sample plot Arapaho, Richardson County, NE, 24 June 1988. (7) Mowed grass. (8) Ecotone. (9) Tall grass.

Future diurnal activity studies should use a shorter sampling interval and focus on the early morning and late afternoon–early evening activity peaks. Areas that merit control or avoidance measures can be extrapolated from the case study presented. The information provided by the principal component analysis did not necessarily imply a prediction model or a causal relationship. It did provide a general description of the population trends of larval *E. alfreddugesi* interacting with environmental variables in a forest edge ecosystem in southeastern Nebraska.

Eutrombicula alfreddugesi presents a difficult control problem. Although Keller & Gouck (1957) demonstrated 10–14-week control of *E. alfreddugesi* in small-plot tests using toxaphene and dieldren, these chemicals are not suitable for widespread use in recreational areas. Eighteen other compounds tested did not provide adequate chigger control (Keller & Gouck 1957). Roberts & Zimmerman (1980) demonstrated significant control using two pyrethroids; however, chigger populations began to rebound within 3–4 wk after treatment. In recent field trials using Dursban, Deltic, and Sevimol at recommended rates, there was no evidence for suitable control of larval *E. alfreddugesi* populations (Clopton 1989). The apparent lack of effective or acceptable area control with available pesticides suggests a control strategy focused on protection of the individual.

Infestation by larval *E. alfreddugesi* can be reduced by personal repellents, avoidance of habitats characteristic of large chigger populations or habitat modification, or combinations of these. Clopton & Gold (1992) reported a significant reduction in *E. alfreddugesi* bite counts using *N,N*-diethyl-3-methylbenzamide (deet)-based personal repellents. Beuscher et al. (1984) tested 9 commercial and 11 experimental repellent compounds against *Leptotrombidium fletcheri* Wormersly & Heaslip, 1943, and found no compound to be significantly more repellent than deet. This study indicates that persons entering chigger-infested areas may reduce their exposure to *E. alfreddugesi* by avoiding ecotone areas and limiting activity in dawn, late afternoon, and early evening hours. Habitat modification by sustained mowing may effectively reduce chigger populations. In combination, these strategies can significantly reduce human exposure to larval *E. alfreddugesi*.

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