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Use of National Weather Station Temperature Records in Field Studies

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ABSTRACT

Temperatures at the soil surface under dense vegetative cover were compared with those from a National Weather Station located 6.6 km away over a period of 14 years in east-central Illinois. Comparisons were made during periods of very low (<0 C), very high (>30 C), and intermediate (5-29 C) temperatures. All temperatures were significantly different between the two sites. Mean daily temperatures recorded at the National Weather Station during periods of very low temperatures were 13.4 C lower than those at the vegetative-moderated soil surface. There was no correlation of mean daily minimum temperatures at the National Weather Station during periods of very low temperatures with those under the vegetation. Mean daily maximum temperatures were 6.1 C and 8.1 C higher at the National Weather Station than at the soil surface during periods of moderate and high temperatures. Usage of temperature data from distant National Weather Stations is inappropriate for estimating effects of temperatures on small mammals living under dense vegetative cover.

INTRODUCTION

Analyses of data from field studies of small mammals frequently test effects of weather conditions on demographic variables such as survival, activity, dispersal, and reproduction (Madison, 1985; Kriegsfeld et al., 2000; Jackson et al., 2001). Time constraints and limited resources often prohibit establishment and monitoring of weather stations within the study site during the course of the study. Or, such analyses are conducted as an afterthought so as to obtain additional information from the data sets. Researchers, therefore, often rely on weather data from existing National Weather Stations located some distance from the site for these analyses (Brady and Slade, 2004). In addition to bias resulting from local differences in weather conditions at the study site and National Weather Station, serious bias results from positioning of recording instruments 1 m above the surface at National Weather Stations. This is an especially important concern when the animals studied limit their activity to below dense vegetation. There is the potential for temperatures below such insulative cover to differ from those in the air above (Geiger, 1965). The magnitude of differences in temperatures measured at National Weather Stations distant from the study area have not been documented.

During the course of a demographic study of small mammals in east-central Illinois (Getz et al., 2001), a temperature station continuously recorded temperatures at the soil surface below a dense stand of bluegrass (*Poa pratensis*), under which there was a mat of dead bluegrass litter. The subjects of this study, prairie vole (*Microtus ochrogaster*), meadow vole (*M. pennsylvanicus*), and short-tailed shrew (*Blarina brevicauda*), utilize small (□3 cm in diameter) runways formed through the dense mat of vegetation and litter on the soil surface. Often the runways are worn □1 cm into the soil.

OBJECTIVE

The objective of this study was to compare temperatures from under the vegetation at a field site with those from a National Weather Station located 6.6 km SW of the study site. Specifically, tested were: (1) the magnitude of differences in temperatures as recorded by a distant weather station from those measured under vegetative cover and (2) the correlation of temperatures recorded at the weather station with those under vegetative cover.

MATERIALS AND METHODS

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The small mammal study site was located within a former bluegrass pasture in the University of Illinois Biological Research Area ("Phillips Tract"), 6 km NE of Urbana, Illinois (40°15'N, 88°28'W). The pasture was released from grazing in June 1971; there was dense vegetative cover, including a mat of dead bluegrass litter, by autumn 1971. Sunlight penetration to the soil surface in the site was only 3.2 ± 0.2% of full sunlight (Getz et al., 2005). The National Weather Station, maintained by the Illinois State Water Survey, was on the Morrow Research Plots on the University of Illinois campus. The Morrow plot weather station was located approximately 120 m to the west and east of tall campus buildings, and 50 m to the north and 90 m to the south of buildings; the moderating effects of campus buildings on wind currents and thus temperature regimens was minimal. The field station was located approximately 200 m southwest of a 25 ha mature deciduous forest and 100 m east of a 20 ha site in which invading trees reached heights of 10 m by the time the temperature study was completed.

Meahods

A Bristol 3-pen recording thermograph was located at a site where vegetation appeared typical of the general study area. Each pen was connected to a 1.8-m cable lead with a temperature probe at the end. The three probes were positioned on the soil surface under undisturbed litter and vegetation at 120° angles from the recorder. The recorder was placed in a wooden shelter for protection from the elements. Temperatures were recorded continuously by ink pens on a circular paper chart. The charts were changed and ink added weekly. Temperature data were obtained from 10 July 1972 through 29 April 1986. National Weather Station records for these dates were provided by the Illinois State Water Survey.

DMMMiMyses

Data selected for analysis were from three general temperature regimens, as recorded at the National Weather Station, during the 14 years the field temperature recorder was operating: (1) from periods of very low temperatures, when daily maximum temperatures

were <0 C; (2) from periods of very high temperatures, when daily maximum temperatures were >30 C; and (3) from periods of moderate temperatures, when daily maximum temperatures were 5-29 C. Specific blocks of time used in the analyses were restricted to periods with at least five consecutive days that met the above requirements. Daily maximum and minimum temperatures, and amount of fluctuation were compiled from the soil surface records. Daily maximum and minimum temperatures were determined by averaging the three pen traces. Data for the same days were compiled from the National Weather Station records.

Statistical Analyses

Significance of differences in maximum and minimum temperatures and amplitudes of fluctuations between the National Weather Station and field measurements were determined by *t*-tests (Zar 1999). Data for periods of high and moderate temperatures were log-transformed. Minimum temperature data sets involved negative numbers and were not log-transformed. Comparisons of transformed and untransformed data sets without negative entries indicated *t*-values on untransformed data were almost identical to those on log-transformed data. Correlation analyses of the high and moderate temperature data sets utilized Pearson's *r* (Zar 1999). Because of negative numbers, Kendall's *tau* (Zar 1999) was used to test for correlations between the National Weather Station and field data during low temperature periods.

RESULTS AND DISCUSSION

All comparisons of temperatures recorded at the National Weather Station differed significantly from those under the vegetation in the study site (Table 1). The greatest magnitude of difference between National Weather Station and soil surface temperatures in the field were mean daily minimum temperatures during periods of very low temperatures, 13.6 C lower at the National Weather Station than under the vegetation in the study site (Table 1). Maximum daily temperatures varied by only 3.9 C between the National Weather Station and field during periods of very low temperatures. During periods of moderate and very high temperatures, mean daily maximum temperatures were 6.2 C and 8.1 C higher at the National Weather Station than at the soil surface in the field, respectively. Mean daily minimum temperatures at the National Weather Station varied little from those recorded at the weather station during these two periods, 1.5 C and 1.8 C, respectively (Table 1).

Amplitudes of fluctuation were greater at the National Weather Station than were those at the soil surface (Table 1). Those at the soil surface differed the most (10.4 C) during periods of very low temperatures and least when temperatures were very high (6.3 C). Daily fluctuations at the National Weather Station differed among the three temperature regimes by only 1.2 C; those at the soil surface differed among the three temperature regimes by 5.3 C, with the least daily fluctuation during periods of low temperatures (Table 1). Except for daily minimum temperatures and amplitudes of fluctuation during periods of very low temperatures, mean daily maximum and minimum temperatures, as well as daily fluctuations in temperatures, at the National Weather Station were significantly correlated with those under the vegetation (Table 1).

Because the small mammals in this study were active at the soil surface, under a dense mat of vegetation, sub-soil temperatures might be most representative of those to which the small mammals were exposed. Although soil temperatures are not normally a part of the records from National Weather Stations, temperature data from 10 cm below the surface at the Morrow Plot station were available for representative periods during the present study. During periods of exceptionally low temperatures, daily minimum soil temperatures (-0.9 ± .2 C) reflected most closely both daily maximum (-0.6 ± .1 C) and minimum (-0.8 ± .1 C) temperatures at the soil surface in the field (daily maximum soil temperature at the Morrow Plot station was +0.8 ± .2 C). During periods of exceptionally high temperatures, daily minimum soil temperatures 10 cm below the surface at the Morrow Plot station most closely reflected daily maximum surface temperatures at the field site (23.9 ± .2 C and 24.3 ± .3 C, respectively; daily maximum soil temperatures were 26.6 ± .3 C; minimum surface temperatures at the field site were 20.1 ± .4 C).

From these observations, use of temperature data from a distant National Weather Station to estimate potential stresses on animals living under dense vegetation has obvious limitations and limited utility. National Weather Station records vastly exaggerate potential low-temperature stresses encountered by the animals and amplitudes of temperature fluctuation during periods of very low temperatures. Further, mean daily maximum temperatures during periods of high and moderate temperatures differed markedly between the National Weather Station and soils surface. Except for minimum temperatures and amplitudes of fluctuation during periods of very low temperatures, temperatures recorded at the National Weather Station were positively correlated with those at the soil surface. It is, however, periods of low-temperature stresses that typically are most important in estimating effects of temperatures on physiological stresses, survival, reproduction, and behavior of small mammals (McDevitt and Speakman, 1994; Kriegsfeld et al., 2000; Jackson et al., 2001).

CONCLUSIONS

The results of this study suggest temperature data from distant National Weather Stations are inappropriate for estimating temperature stresses encountered by small mammals living under dense vegetation. If available, soil temperature data from 10 cm below the surface might be utilized to approximate surface temperatures under vegetation at a field site. Unfortunately, soil temperatures are not typically recorded at National Weather Stations. Methods for measuring temperatures at the local site and at the level at which the subject animals live should be utilized.

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Table 1. Comparison of temperatures (mean daily °C ± S.E.) recorded at a National Weather Station with those at the soil surface under a dense mat of bluegrass (*Poa pratensis*) vegetation, in east-central Illinois.

Temperature regime	Weather station[e]	Field surface[e]	Correlations	
			r/*tau*[f]	P
Low temperature periods[a] (152)[d]				
Daily maximum temperatures	-5.5 ± 0.4	-1.6 ± 0.3	0.137	0.018
Daily minimum temperatures	-15.5 ± 0.4	-1.9 ± 0.3	0.074	0.200
Daily fluctuations	10.9 ± 0.8	0.5 ± 0.1	0.054	0.403
Moderate temperature periods[b] (141)[d]				
Daily maximum temperatures	21.0 ± 0.7	14.8 ± 0.7	0.777	<0.001
Daily minimum temperatures	9.2 ± 0.6	10.7 ± 0.6	0.750	<0.001
Daily fluctuations	11.4 ± 0.3	3.8 ± 0.2	0.392	<0.001
High temperature periods[c] (159)[d]				
Daily maximum temperatures	32.7 ± 0.1	24.6 ± 0.3	0.258	0.001
Daily minimum temperatures	20.7 ± 0.2	18.9 ± 0.2	0.376	<0.001
Daily fluctuations	12.1 ± 0.2	5.8 ± 0.2	0.223	0.005

[a] Low temperature periods, daily maximum temperature at weather station <0 C.
[b] Moderate temperature periods, daily maximum 5-29 C.
[c] High temperature periods, daily maximum >30 C.
[d] Number of days in each sample in parentheses.
[e] All differences between weather station and field means are significant at <0.001; t-test).
[f] Correlations: moderate and high temperature periods, Pearson's *r*; low temperature periods, Kendall's *tau*.