MICROCLIMATE, VEGETATION COVER, AND LOCAL DISTRIBUTION OF THE MEADOW VOLE

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ABSTRACT. — A comparison was made of the microclimate of the meadow vole, *Microtus pennsylvanicus,* in situations with varying amounts of cover. Substrate and surface air temperatures were higher in areas with sparse cover (not utilized by meadow voles) than in optimal habitats with dense cover. Relative humidities were higher in the optimal habitats than in situations not inhabited. There was no correlation between absolute humidity and amount of vegetation cover. Only the higher temperatures in areas with sparse vegetation have the potential of causing the voles to avoid these sites. Relative and absolute humidities were not low enough in the sites with sparse cover to place a serious physiological stress on the voles. Humidity does not appear to play a significant role in the avoidance of areas with sparse vegetation by the meadow vole.

INTRODUCTION

The local distribution of the meadow vole, *Microtus pennsylvanicus,* has been correlated with moisture (Getz, 1961, 1963; Lantz, 1907; Findley, 1954; DeCoursey, 1957) and amount of vegetation cover (Getz, 1961, 1970b; Pearson, 1959; Mossman, 1955; Eadie, 1953; Zimmerman, 1965). The actual factors involved in these correlations have not been determined, however; microclimate, especially humidity, has been suggested as a possible factor (Getz, 1963).

Data comparing the microclimate of moist and dry graminoid situations (Getz, 1965, 1970a) indicate that humidity differences between such situations are slight. Humidity apparently is not responsible for higher population densities of the meadow vole in moist marshes. The above studies compared situations in which there was dense cover in both the moist and dry habitats. Microclimate data at the level of vole runways are not available from graminoid sites with varying densities of cover. The data presented in a prior paper (Getz, 1970b) which compared areas with dense and sparse cover were all taken in a wet marsh. Humidity differences would not be expected to be great in areas with saturated substrates.

During the summer of 1968 data were obtained in southern Wisconsin which aid in evaluating the significance of microclimate on the local distribution of the meadow vole. These data were obtained in an area with varying amounts of vegetation cover; the sites included those deemed optimal for the meadow vole as well as sites which the meadow vole did not utilize (Getz, 1970a).

DESCRIPTION OF STUDY AREAS

All work was conducted in the University of Wisconsin Arboretum, Madison, Wisconsin. Five stations, all in the southern part of the Grady Tract, were selected for the main study; other stations in this tract and elsewhere in the Arboretum were spot-checked for comparison. The five main stations were all within 100 m of each other.

Station 1 was in a stand of *Agropyron repens*. The vegetation was 30-40 cm tall; litter formed a dense mat over the surface. Light penetration through the vegetation was only 0.02% (light penetration was used as an index of amount of cover present; see below and Table 1. Station 2 was in blue-grass (*Poa pratensis*) which formed a dense mat 20-30 cm above the surface. The total cover was less than that of Station 1 (1.1% light penetration). Topographically, both Stations 1 and 2 were 20-30 cm higher than the other 3 stations. Station 3 was in a low marsh which supported a pure stand of *Carex lanuginosa*. The vegetation at this station was 40-50 cm tall and had a cover value similar to that of Station 2 (Table I). Station 4 was in an area supporting a relatively sparse growth of various species of grasses and forbs. The average height of the vegetation was 30 cm and the cover approximately 1/10th that of Stations 2 and 3. Station 5 was in an area supporting a very sparse growth of several species of grasses and forbs. The height of the vegetation was 15-20 cm. The cover was so sparse that the surface was relatively exposed in most places; light penetration was high (17.5%).

In addition to the main study area, various other sites were spot-checked. One included a mowed blue-grass area. There was a very dense growth of grass in this area; the surface was completely covered with a mat of green vegetation. Vegetation height was only 2-5 cm at the site studied. The microclimate measurements were therefore taken in the "crown" of the vegetation, i.e., within the green leaves. Spot-checks were also made under a stand of young oak (*Quercus* spp.) shrubs (2 m tall). Crown coverage of the oaks in this site was 95-100%; there was no understory of grass or forbs. The measurements were made over leaf litter 2-3 cm thick.

Table 1.—Soil temperature, soil moisture, and light penetration at the main study stations. See text for techniques.

	Date	Station					Mowed Blue-Grass	Shrubs
		1	2	3	4	5		
Soil temp. (C)	2 Aug.							
Surface		24.6	26.8	26.8	29.3	30.4	32.8	25.5
—7 cm		20.8	22.4	21.4	24.1	25.9	29.5	21.8
Soil moisture								
g/280 cm^3	25 July	112	116	142	163	153	108	103
	2 Aug.	102	107	133	147	139	55	68
% Saturation	25 July	35.4	34.7	42.6	50.1	43.7	26.0	29.1
	2 Aug.	30.8	31.5	40.2	46.5	39.7	13.4	22.5
Per cent light penetration[1]	2 Aug.	0.02	1.1	1.0	10.5	17.5	61.0	....

[1] % of full sunlight.

Some data were obtained from a dry south-facing hillside which supported a moderately dense stand of bluegrass; the vegetation was 20-30 cm tall and formed a less dense cover (4.1% light penetration) than that at Station 2. Comparative data were taken in an adjacent site (2 m distance) which was mowed. The vegetation was much more sparse in this area than in the mowed area described above; the surface was almost entirely exposed (47.5% light penetration).

A few measurements were also taken in a tall-sedge (*Carex* sp.) marsh, the typical habitat of the meadow vole in this region, for comparison with the drier sites. The sedges grew in clones approximately 10-20 cm in diameter at the base and 1.0-1.5 m tall. The bases of the clones were 30-50 cm apart; the crown coverage was 100%, however. Light penetration was 1-2%.

Observations of vole sign and live-trapping were conducted in the above described vegetation types during the summers of 1967 and 1968. These indicated that Station 3 and the tall-sedge marsh area were the optimal habitats of the meadow vole (Getz, 1970a). Late in the summer of 1968 the vole population had also extended out into areas including Stations 1, 2, 4 and the unmowed hillside. Station 5, the two mowed areas, and the shrub area were not utilized by the meadow vole. These latter areas are not considered suitable habitats for this species.

Methods

A series of microclimate measurements (1 cm above the substrate surface) were made at approximately 2-hour intervals between 0745 and 1900 on 2 August 1968. Another series were made between 1430 and 2045 on 22 July 1968. Data were not obtained during the night since these observations and other spot-checks indicated all stations had similar temperature and relative humidities between 2000 and 0800; relative humidity was 95-100% during this latter period. Five other series of spot-checks of all stations were made during July and August. All measurements were made on clear days at least 3 days after the last rain.

Surface microclimate. — A thermistor psychrometer was used to obtain dry-bulb and wet-bulb readings at the desired sites. These data gave surface air temperatures and were used to calculate relative and absolute humidities.

Three sites (within a 10 m radius) were sampled at each station; three sets of dry and wet-bulb readings were taken at each site (all within a 1 m radius); there were therefore nine sets of readings from each station each time it was checked.

Measurements were taken 1 cm above the surface. The barrel of the psychrometer was inserted through the vegetation so as to keep to a minimum disturbance to the crown cover and litter layer. All measurements were taken at the exact same place during each series of checks. The hole in the litter was closed after each set of measurements was completed. One set of dry and wet bulb readings was also taken 1 m above the surface at each site. These provided comparison of above-surface air temperatures at the various stations.

The stations were visited in the same sequence; it took 35-40 min to make the complete set of measurements. When other stations were spot-checked, all were completed within 30 min after the measurements at the regular stations were finished. See also Getz (1970a) for other microclimate data obtained in the same study area.

Soil temperature. — A Yellowsprings telethermometer with an attached hypodermic thermistor probe was used to measure substrate temperatures. Substrate temperatures were measured at the same number of sites as described above. Three sets of surface (sensitive portion of the probe only touching the surface) and subsurface (7 cm below the surface) temperature readings were taken at each site.

Soil moisture. — a gravimetric method (Getz, 1970a) was used to estimate substrate moisture; data were obtained both in terms of per cent saturation and g water/280 cm^3 of substrate. One 280 cm^3 plug of substrate was taken at each station. Two sets of samples were taken, 25 July and 2 August 1968.

Light penetration. — Amount of light penetration through the vegetation was used as an index of total vegetation cover at each station. A previously described device (Getz, 1968) was used to measure light intensity above the vegetation and at the surface of the substrate. This device creates a minimum of disturbance to the vegetation crown and litter. One above-surface reading and 12 surface readings were taken at each station. The two most aberrant surface readings at each station were omitted from the calculations. Readings were taken 1100-1200 on a cloudless day.

Results

Main Study Area

Substrate moisture. — There were frequent showers in southern Wisconsin during the summer of 1968. As a result, substrate moisture was relatively high at all stations. There was no consistent correlation between amount of vegetation cover and substrate moisture (Table 1). In general the two areas with less vegetation had higher substrate moisture while those with the greatest amount of cover were drier. The former stations were slightly lower topographically than the latter two. Although Station 3 was the lowest of the five, the substrate moisture of this station was intermediate between that at the other stations. The relatively slight microrelief differences (combined with the frequent rains) appeared to be as important as did the amount of vegetation cover in influencing substrate moisture.

Substrate temperature.—Both surface and subsurface temperatures tended to be correlated with the amount of vegetation cover at each site; mid-day temperatures were higher and diel fluctuations greater where the vegetation was sparse. The maximum difference in substrate surface temperatures between stations was 5.8 C; maximum subsurface difference was 5.1 C (Table 1). These differences are essentially the same as those observed in the surface air temperatures (see below). Although substrate temperatures were not measured during the night, there would be less difference in substrate temperature during these times than during mid-day. Substrate temperatures would also vary little on overcast days.

Surface air temperatures. — Air temperatures 1 m above the surface did not differ significantly between any of the various stations studied. Wind currents apparently caused enough mixing of air to prevent development of different temperature profiles at each station.

As might be expected, surface air temperatures in general directly reflected the amount of vegetation cover; higher daytime temperatures and greater diel fluctuations occurred at the sites with lesser cover than at those with greater cover. Differences in temperatures between the five stations occurred only during the period of 1000 to 1600. The maximum recorded difference was 7.5 C; observed differences were normally less than this, however (Figs. 1, 2; Table 2).

TABLE 2.—Spot checks of air temperatures (C) 1 cm above the surface; values represent an average of 9 readings at each station.

Date	Time	Station					Mowed Blue-Grass	Shrubs
		1	2	3	4	5		
21 July	1420–1510	28.5	29.4	29.6	29.9	30.0	28.9	28.2
23 July	0710–0750	14.8	15.2	14.6	15.2	15.6	16.2	14.9
25 July	1420–1450	22.4	23.2	25.4	26.9	27.3	28.4	24.9
29 July	1350–1430	22.1	25.0	22.5	25.8	26.8	24.9	23.7
26 August	1430–1540	18.6	20.3	18.7	19.7	24.0	24.1	20.3

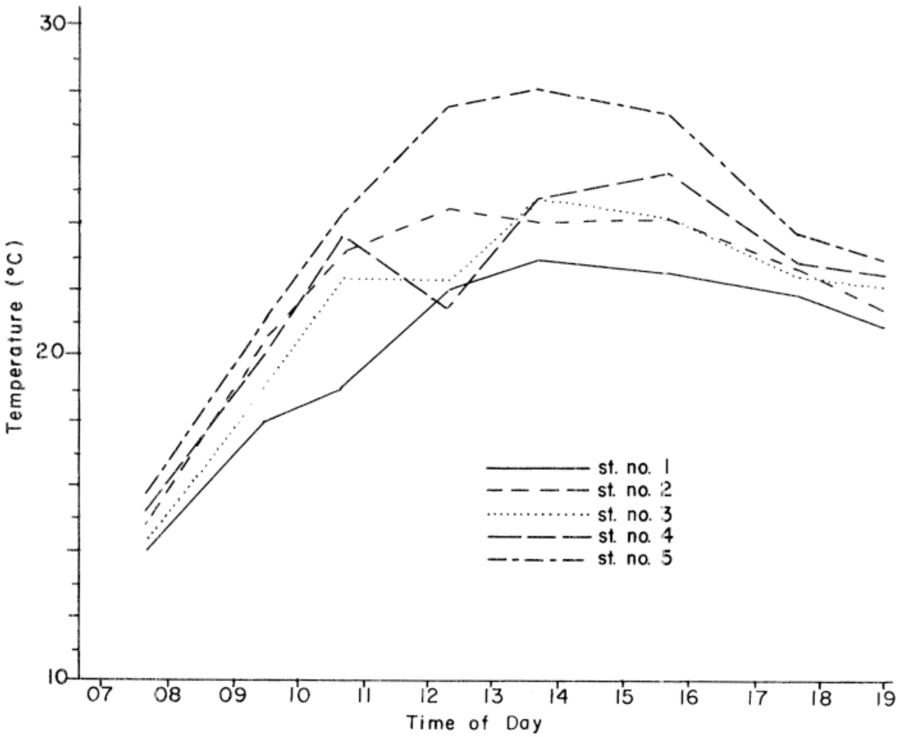

FIGURE 1. Air temperatures 1 cm above the surface, 2 August 1968.

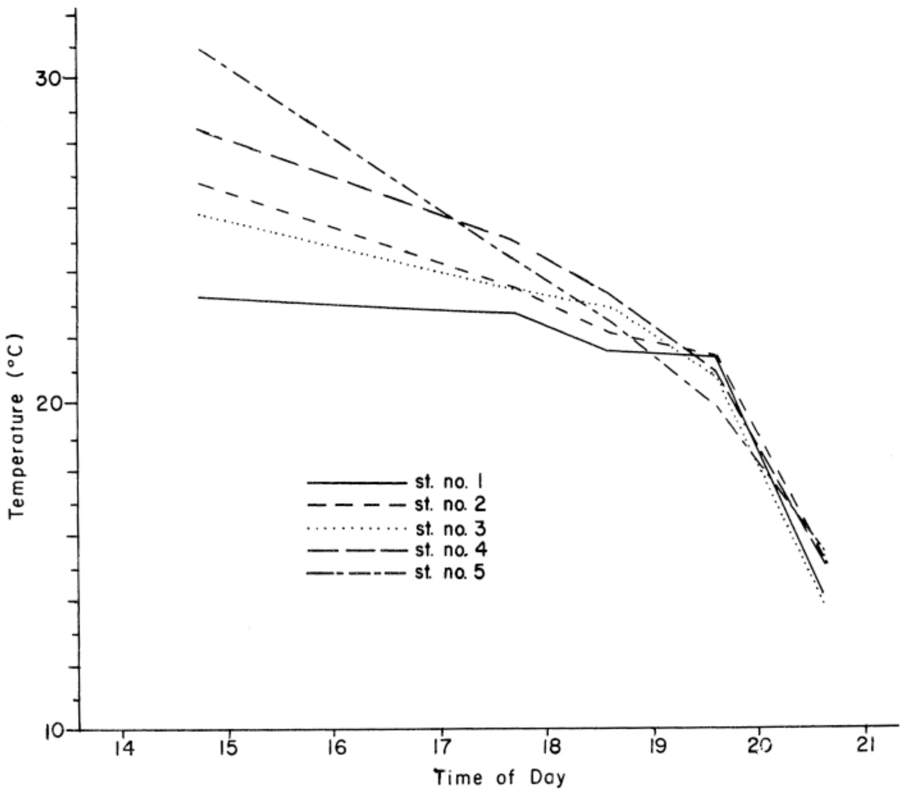

FIGURE 2. Air temperatures 1 cm above the surface, 22 July 1968.

Spot checks revealed that at night and on overcast days there was essentially no difference in surface air temperatures between the stations with sparse cover and those with considerable cover.

Relative humidity. — There was no significant difference in relative humidity 1 m above the surface between any of the stations studied.

Major differences in surface relative humidity between the five stations existed only during the period of 1000-2000; at other times differences were less than 5% (Fig. 2; Table 3). Between 2000 and 0800 relative humidity was approximately 95% at all stations.

There appeared to be more similarities between relative humidity and the amount of cover than between relative humidity and substrate moisture (Figs. 3, 4; Tables 1 & 3.) The lowest relative humidities were observed where cover was sparse and the highest where there was the most cover.

The maximum difference in relative humidity between the station with the sparsest cover and that with the most dense cover was 20%. The maximum difference between other stations was only 11%, however. Even at the stations with sparse cover, relative humidity seldom went below 60%; normally humidities

TABLE 3. — Spot checks of relative humidity (%) 1 cm above the surface; values represent average of 9 readings at each station.

Date	Time	Station 1	2	3	4	5	Mowed Blue-Grass	Shrubs
21 July	1420–1510	82.7	75.7	71.2	67.8	62.7	81.4	70.5
23 July	0710–0750	98.3	97.3	97.0	95.7	95.7	93.7	94.0
25 July	1420–1450	90.0	90.8	81.7	87.0	75.2	90.8	79.3
29 July	1350–1430	84.8	80.9	77.9	80.2	71.1	93.0	69.7
26 August	1430–1540	77.6	76.1	73.9	79.8	67.1	87.0	59.7

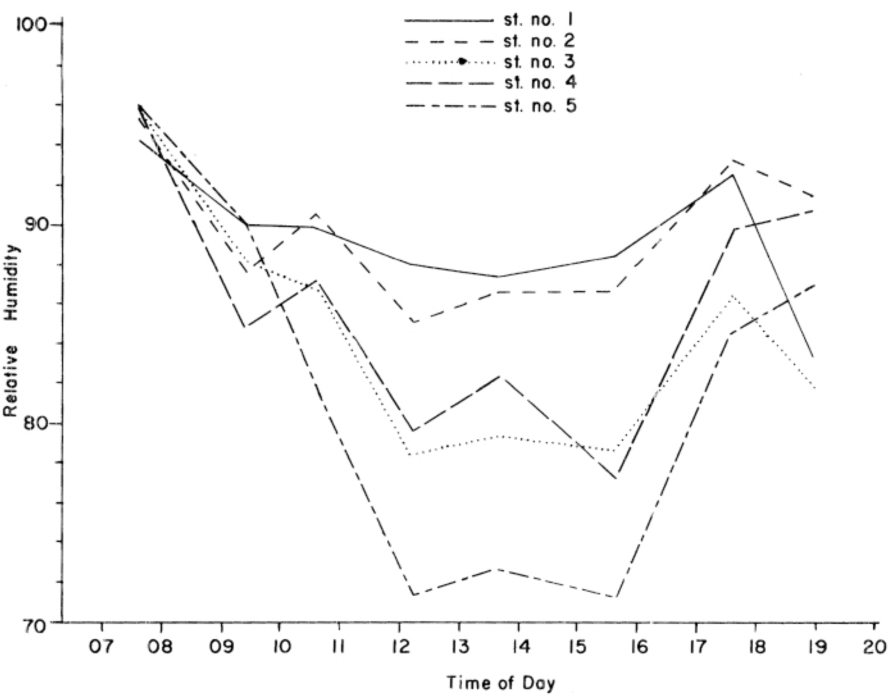

FIGURE 3. Relative humidities 1 cm above the surface, 2 August 1968.

were at least 70%. It therefore appears that differences in relative humidity between optimal habitats and situations where the meadow vole does not occur are not great.

Absolute humidity. — Absolute humidities were highest during the day. During the night and on overcast, humid or rainy days the air at the surface was essentially saturated regardless of the amount of vegetation cover. Absolute humidity at these times was essentially a function of surface air temperature. Ab-

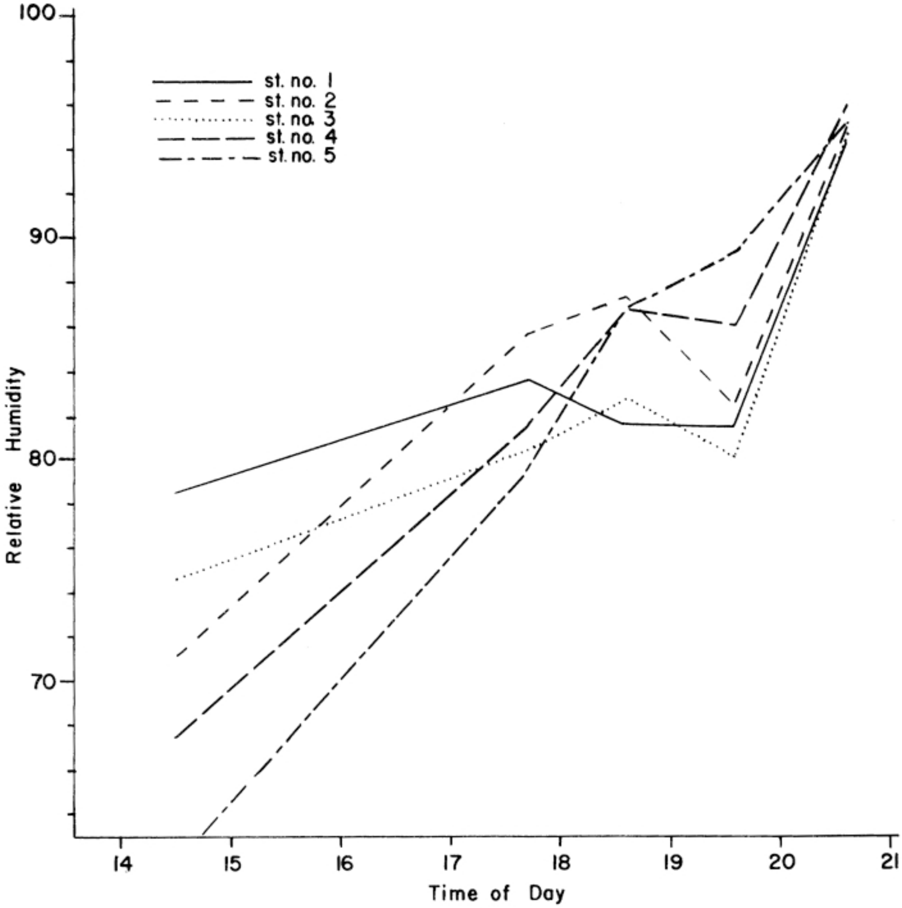

FIGURE 4. Relative humidities 1 cm above the surface, 22 July 1968.

solute humidity differences between stations existed only during the period of 0900 to 1900. The maximum difference between any two stations was 5.8 mg/l normally the differences were much less than this (Figs. 5, 6; Table 4).

Although there was no distinct correlation between absolute humidity and amount of vegetation cover, the higher absolute humidities frequently occurred at the stations with lesser cover. This is a reflection of the significance of temperature on absolute humidity; the higher midday surface air temperatures (and thus the greater capacity for the air to hold water) in the area with less cover more than compensated for the lower relative humidity at these sites.

Other Areas

Mowed blue grass. — Air temperatures 1 cm above the surface were not significantly higher than those

TABLE 4. — Spot checks of absolute humidity (mg/l) 1 cm above the surface; values represent average of 9 readings at each station.

Date	Time	Station 1	Station 2	Station 3	Station 4	Station 5	Mowed Blue-Grass	Shrubs
21 July	1420–1510	22.5	25.5	22.5	26.6	25.6	29.8	20.3
23 July	0710–0750	13.4	13.5	13.1	13.1	13.4	13.6	12.7
25 July	1420–1450	19.7	18.8	21.7	25.5	22.3	22.0	16.5
29 July	1350–1430	18.2	21.1	17.5	21.9	20.3	23.9	16.3
26 August	1430–1540	13.1	14.4	13.0	14.7	16.3	21.1	11.5

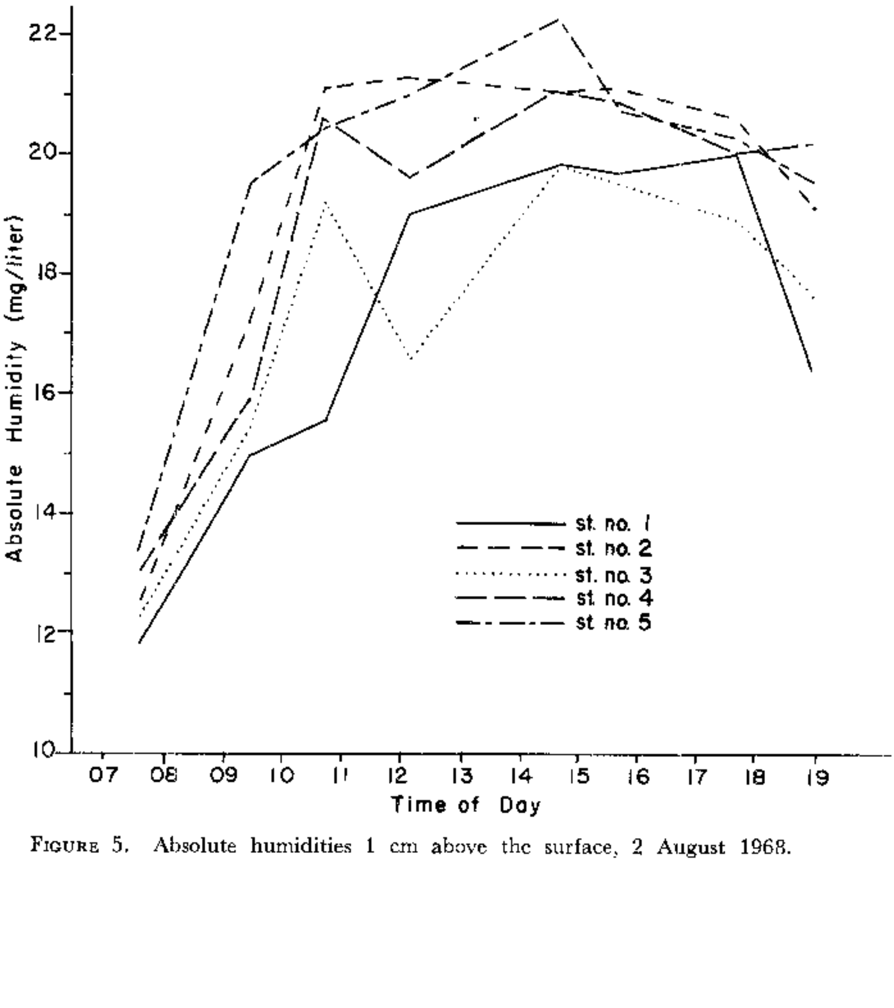

FIGURE 5. Absolute humidities 1 cm above the surface, 2 August 1968.

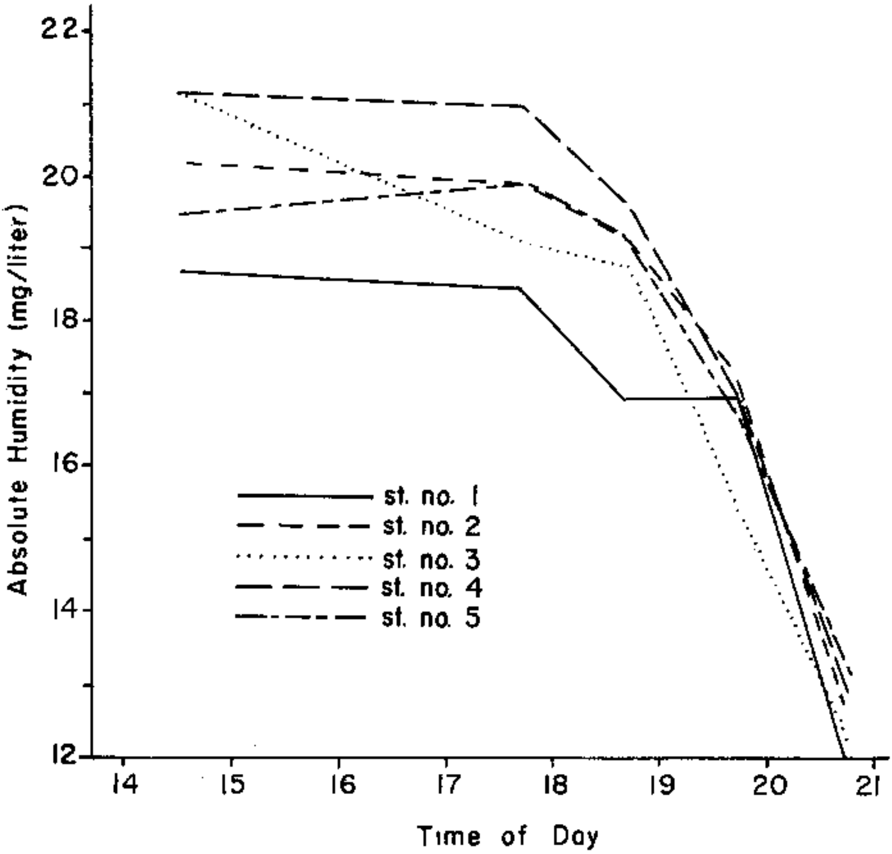

FIGURE 6. Absolute humidities 1 cm above the surface, 22 July 1968.

at other stations with more cover (Tables 1 and 2). Since measurements taken 1 cm above the surface were essentially in the vegetation "crown", transpiration cooling may be responsible for the lower air temperatures.

Relative humidity 1 cm above the surface was normally as high as or higher than (up to 10% higher) that at any station with dense cover (Table 3). The measurements were probably high owing to moisture released via transpiration. The absolute humidities in the mowed area were normally higher than those at the stations with the most cover (Table 4).

Shrub area. — Surface air temperatures were lower than most of the stations with graminoid cover (normally temperatures at the former were intermediate between the extremes of the five main stations). The crown cover of the shrubs shaded the area sufficiently to modify surface temperatures (Table 2).

Surface relative humidity was essentially the same as that recorded at Station 5 (Table 3). The combined low relative humidity and low temperatures resulted in lower absolute humidities in the shrub area than were normally recorded in the graminoid areas (Table 4).

Dry hillside. — In general the surface air temperatures in the unmowed site were higher than at any of the five main stations. The relative humidities were intermediate to those observed at the other sites (except for the 26 August reading); absolute humidities were similar to those at the five main stations (Table 5).

Surface air temperatures were up to 4.2 C higher and relative humidities as much as 21% lower in the mowed site than in the unmowed area. Absolute humidities were normally 2-5 mg/l higher in the mowed area. The differences from the other mowed area undoubtedly resulted from the more sparse growth of vegetation in the hillside area. When the grass was mowed, the remaining vegetation was so sparse that transpiration was not as significant a factor in the microclimate as it was in the other mowed area.

Marsh. — Although only 3 spot-checks were made of microclimate at this site, they did not indicate significant differences from drier sites with dense vegetation (Table 5). In general, relative and absolute humidities were actually slightly less than at sites with dense cover. The green part of the leaves in this area were some distance above the surface (the parts close to the surface were dried out) so that there was little transpiration near the surface.

The more open character of the vegetation permitted drying of the soil surface; this apparently reduced evaporation from the surface. The humidity at the surface in this type of marsh vegetation is therefore lower than that at drier sites where there is dense, but low, vegetation cover. In any event, air humidity near the surface was not higher in this type of marsh (optimal habitat for the meadow vole) than in drier upland sites (marginal habitats of the meadow vole).

Discussion

As would be expected there was in general an inverse relationship between amount of vegetation cover and substrate and surface air temperatures. The greater the cover, the lesser the extremes in substrate and surface air temperatures. Relative humidity was more positively related to vegetation cover; sites with more cover had higher relative humidities.

Table 5. — Surface air temperatures and relative (RH) and absolute (AH) humidities at other sites in the vicinity of the main study area. Values represent averages of 9 readings at each site.

Date	Time	Mowed Hillside			Unmowed Hillside			Marsh		
		Temp. (C)	RH %	AH mg/l	Temp. (C)	RH %	AH mg/l	Temp. (C)	RH %	AH mg/l
25 July	1500	30.1	70.8	22.4	27.9	80.9	19.5	......	......	......
29 July	1445	28.2	62.4	19.2	25.7	79.0	21.3	......	......	......
2 August	1000	26.4	74.6	15.3	22.2	92.0	20.0	22.2	86.0	18.5
2 August	1620	27.9	55.9	17.9	25.6	77.2	20.1	22.5	80.0	19.7
26 August	1610	26.4	50.7	14.3	23.2	58.5	13.5	21.7	74.6	15.9

Owing to the higher air temperatures in sites with less cover, there was no direct relationship between cover and absolute humidities. The absolute humidity in the sites with the least cover were normally slightly higher than in those with the most cover, however.

The magnitudes of difference between the microclimate of the various sites included in the present study were relatively small. The vegetation types studied ranged from optimal habitats to those not inhabited by the meadow vole; the microclimate of the optimal habitats of this species is therefore only slightly different from that of other vegetated situations not normally utilized. Even when sites such as closely mowed areas are considered, microclimates do not differ greatly from situations in which the meadow vole does occur. In close-clipped, dense vegetation the microclimate actually may be similar to that in optimal habitats.

Of the factors studied, air and substrate temperatures varied the most. The 5 to 7 C differences that were recorded may be sufficient to make the sparsely vegetated sites unsuitable for the meadow vole. Data pertaining to the temperature tolerances and preferences of the meadow vole are not available, however.

Relative humidity differences between the various cover types were at the most 20% and normally in the order of only 10%. These differences do not appear to be great enough for relative humidity to place a physiological stress on the voles, if they were to attempt to inhabit situations with sparse cover. Although the water requirements of the meadow vole vary with relative humidity, such requirements are significantly higher only at relative humidities of less than 50% (Getz, 1963). The lowest humidity recorded in the present study was above 50% (normally they were above 70%).

Differences in microclimates occurred only for about a 9-10 hr period during mid-day, and then only on clear days. On overcast days and from 2000 to 1000 there was essentially no difference in the microclimate between sparse-cover and dense-cover situations. Any stress placed on the meadow vole by microclimatic differences would therefore be further reduced. It is possible, however, that the higher temperatures during mid-day on clear days would be sufficient to keep the voles from inhabiting areas with sparse cover.

Another study in same area (Getz, 1970a) also failed to find sufficient microclimate differences, humidity in particular, to account for the local distributional pattern of the meadow vole.

The results of this study and previous ones (Getz, 1965; 1970a, 1970b) make it rather obvious that relative humidity is not a significant factor in the local distribution of the meadow vole. This applies to situations involving varying amounts of cover as well as moist and dry habitats. The magnitude of habitat differences and the amount of time such differences do exist are not sufficient to place a significant stress on the voles.

Studies of temperature tolerances and preferences are required to estimate the actual significance of temperature on the local distribution of the meadow vole. It is probable that other factors such as behavioral preferences, and predation (in the case of varying cover; Getz, 1970b) may also be at least partly responsible for the association of the meadow vole with dense vegetation.

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