MICROCLIMATE AS A DETERMINING ELEMENT IN THE DISTRIBUTION OF TICKS AND THEIR DEVELOPMENTAL CYCLES

M. DANIEL

Institute of Parasitology, Czechoslovak Academy of Sciences, Prague

Abstract. The paper deals with the problem of interrelationship between macroclimate of the region, mesoclimate of the biotope studied and microclimate of the tick niches proper, necessary for the research of tick ecology. New methods for the solution of microclimatological studies are proposed and the relationship between macro-and mesoclimate, or that between temperature in the tick cage and environment, is formulated. In choosing optimal intervals of data acquisition a two-hour interval (every even hour of the day) has proved to be the most suitable.

Most papers attempting to analyze the influence of meteorological factors on the existence, behaviour, reproduction cycles etc. of ticks, are based on measurements recorded by nearest observation field stations of the public meteorological service with standard equipment and observation programme. It is true that in this way general and comparable information can be obtained which is applicable for wide regions, but such data are utterly lacking the peculiarities due to microlief of terrain, vegetation, shade, character of soil, thickness of the leaf litter layer etc. It should be stressed, however, that the microspaces in the upper layers of soil and litter constitute the tick niches proper in which the major part of their life cycle takes place.

We have studied in detail the problem of suitability of using the data provided by public observation network for the tick research and arrived at the conclusion that such data do not reflect the actual conditions in which the ticks live and develop and the derived relationships are therefore of limited and in many respects only guiding significance. The standard meteorological box installed in the biotope studied is not satisfactory either. The main shortcoming is the excessive inaccuracy of measurements and their insufficient number taken during the day (i.e. readings at 7, 14 and 21 hours). For this purpose the recording apparatuses such as hydro- and thermographs are not satisfactory either. In view of the fact that the problems tackled are distinctly relating to micrometeorology, it is necessary to employ adequate apparatuses and working procedures adapted for long-term measurements taken at short intervals. These requirements are met with by methods published by Daniel (1965) having the following assets:

— temperature and humidity probes based on pearl thermistors are of tiny size and can measure the values in actual microspaces;

— a small bulk of the probes enables rapid reactions to small changes of temperature; the temperature inertia does not practically exist

— on the basis of these thermistors psychrometers for humidity recordings can be easily produced

— the measurement and recording apparatuses can be placed directly in the terrain and recordings taken continuously for a long period

— the values can be transmitted to a relatively long distance, so that data from different microbiotopes can be concentrated in one recording unit.
The first application of these methods in tick research is presented in the paper of Daniel and Černý (1967). Under conditions of a regularly inundated forest in southern Moravia two closely situated sites with no apparent differences in vegetation, but with a different microlief were observed. One was characterized by the occurrence of ticks, and the other by their absence. The microclimate showed differences, but the data concerning macroclimate were common to both sites, of course.

After these perspective findings the methods for evaluation of micrometeorological recordings (Daniel 1970) were elaborated, consisting in automatic digitalization of the curves recorded and in subsequent calculation carried out on a computer, including necessary programmes. In the subsequent season in one site of the same inundated forest the relationship between macro-, meso- and microclimate was analyzed. The data of the nearest station of the State observation network (about 7 km away) were taken as macroclimate, the data from the standard meteorological box installed directly in the experimental site were considered as mesoclimatic and the data measured in the air near the ground at the experimental site were regarded as microclimate. A statistical comparison of daily mean temperatures, daily minima and daily maxima resulted in:

<table>
<thead>
<tr>
<th>Pair tested</th>
<th>Significance level tested</th>
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<tr>
<td></td>
<td>daily mean temperature</td>
</tr>
<tr>
<td>micro — meso</td>
<td>NS</td>
</tr>
<tr>
<td>meso — macro</td>
<td>1 %</td>
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<tr>
<td>micro — macro</td>
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(NS = not significant at 5 % level)

On the basis of these results we have elaborated a project of three-years studies on the effects of microclimate on the total development of *Ixodes ricinus* under conditions of southern Moravia, but in the biotope of thermophilic oak forest. Prior to setting up the more elaborate main experiment a trial run was made, from which it could be gathered that the ticks were also influenced in their further development by the soil microclimate during hibernation, and which enabled a mathematical formulation of the relationship between macro-and mesoclimatic. A formula had to be determined by means of which the temperature characteristics of mesoclimatic could be accurately calculated from the data of macroclimate. This applies to mean maxima and minima of daily temperature. Let us use for macroclimate the following designation: daily mean temperature $x_1$, daily temperature maximum $x_2$ and daily temperature minimum $x_3$. Analogically for mesoclimatic let us designate daily mean temperature $y_1$, daily temperature maximum $y_2$ and daily temperature minimum $y_3$.*

The required dependence is constructed by multiple linear regression. We assume that the dependence of the variable $y_1$ on the variables $x_1$, $x_2$, $x_3$ can be described in terms of multiple linear regression, i.e.

$$y_1 = ax_1 + bx_2 + cx_3 + d + e,$$

*) The presented method of data analysis was used by the team of workers of the Mathematical Centre of Biological Institutes, headed by Dr. M. Chytìl CSSR and under the guidance of Dr. Reinhardtová of the Hydrometeorological Institute in Prague.
where $\epsilon$ is the residual random variable with zero expectation. The estimation of coefficients $a, b, c, d$ is carried out by method of least squares, i.e. by minimizing the expression

$$\Sigma(y_1 - ax_1 - bx_2 - cx_3 - d)^2$$

This condition from the mathematical aspect leads to the system of the so-called normal equations by the solution of which we obtain the sought values of coefficients $a, b, c, d$. An analogous procedure is used in constructing the regression equation for $y_2$ and $y_3$. After all calculations are made the following theoretical dependences were obtained for the conditions of our experiment:

$$y_1 = 0.786x_1 + 0.157x_2 + 0.120x_3 - 0.62$$
$$y_2 = 0.928x_1 + 0.435x_2 + 0.147x_3 - 0.027$$
$$y_3 = 0.084x_1 + 0.119x_2 + 0.765x_3 - 1.28$$

These mathematical relationships demonstrate the complexity of the whole problem and it should be noted that in the final version they can be applied locally in a limited way in the experimental site. In our instance this means that after the first season which provided data for the calculation of coefficients, satisfactory calculations of the mesoclimatic could be made from the values of macroclimate.

Simultaneously the mathematical relationship and method of determining the soil temperature (or the temperature in the cage in which the ticks were placed in different soil layers) and a series of temperatures taken at the ground surface were traced and relevant coefficients were calculated. For the determination of soil temperature to the depth of 20 cm a series of mean values from preceding seven days appears to be sufficient, in case of greater depths a series of mean values from two weeks is necessary.

All previous micrometeorological measurements were evaluated by the same team of workers in the programme named as the problem of choice of optimal intervals in microclimatological measurements. It is one of the basic organizationally and economically highly important problems. It serves as a basis for determining the density of digitalization of recordings in joint temperature recordings. Solving the problem, partly some models dealing with probability distributions of extreme and mean values, partly the approach based on spectral analysis of the examined time series were used irrespective of one another. In this way different intervals of data digitalization and the corresponding exactitudes of estimation of considered characteristics ($\epsilon$) were established. In further practice every even hour (i.e. 12 times daily) was chosen as the most suitable interval of data acquisition, which guarantees the exactness in assessing daily mean temperatures as 0.5 $^\circ$C, and 2 $^\circ$C with extreme values.

This result served as a basis for a three-year experiment in tracing the developmental cycle of *Ixodes ricinus* in three biotopes within the South Moravian thermophilic oak forest. Apart from the initial arrangement (Daniel 1965, 1970) an automated data acquisition was started by means of the recording device ZAZA 16 developed by the workers of the Institute of the Theory of Information and Automation, Czechoslovak Academy of Sciences. The device enabled to record the measured values according to programme prepared in advance on a punch tape applicable directly for a computer.

As for the microclimate, the rich material available confirmed the fact that at distances of several scores of meters there are sufficient differences which might fundamentally affect the existence and development of ticks. In this respect, e.g. the different speed of development is enough to mention (Daniel et al. 1976, 1977). The interrelationship between microclimatic factors is not unchangeable, it undergoes changes as regards individual years and separate seasons as well.
The factual material presented and discussed suggests that new methods for microclimatic measurements should be proposed in ixodological research. If detailed exact and continuous semi and fully automated measurements cannot be secured, it is necessary to meet the following requirements:
a) to place the meteorological box directly in the biotope studied, in order to acquire the data on mesoclimate
b) in the site with the highest tick density within the biotope studied to secure a microclimatological research including measurements of air temperatures near the ground and on the ground surface
c) to use the data supplied by the meteorological stations of the public network only for characterization and comparison of higher orders, but not for interpretation of phenomena governed strictly by microclimate.

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M. D., Parasitologický ústav ČSAV, Flemingovo n. 2, 166 32 Praha 6, ČSSR