# THE TICKPRO COMPUTER PROGRAM FOR PREDICTING *IXODES RICINUS* HOST-SEEKING ACTIVITY AND THE WARNING SYSTEM PUBLISHED ON WEBSITES

**Milan Daniel[1], Tomáš Vráblík[2], Jaroslav Valter[2], Bohumír Kříž[1], Vlasta Danielová[1]**
[1]National Institute of Public Health, Prague, Czech Republic
[2]Czech Hydrometeorological Institute, Prague, Czech Republic

**SUMMARY**

The computer program with the acronym TICKPRO (tick prognosis) facilitates medium-range forecasts of the level of host-seeking activity in ticks within a 1–4 day horizon. The program is based on the medium-range weather forecast routinely produced at the Czech Hydrometeorological Institute (CHMI), as well as on previously developed mathematical models describing the correlation of meteorological factors with the host-seeking activity of *Ixodes ricinus*.

These models are based on a 6-year whole-season monitoring of *I. ricinus* host-seeking activity on experimental fields in the Central Bohemia Region in a typical habitat, oakhornbeam forest, where tick-borne encephalitis (TBE) virus and *Borrelia burgdorferi* s.str., *B. afzelii*, and *B. garinii* have been found. Meteorological data provided by the CHMI meteorological station in Prague-Libuš were used, and during the development of the forecasting algorithm micrometeorological data have been collected directly at the tick monitoring sites under selected synoptic weather situations. In the TICKPRO program, the two most successful models utilized ambient air temperature, quantity of atmospheric precipitation, and relative air humidity.

The prediction determines 5 levels of risk of attack according to the current proportion of host-seeking ticks, and thus determines the risk of TBE infection. The levels of risk defined by the TICKPRO program are supplemented by instructions on how to prepare oneself for entering sites with potential tick occurrence, how to move around once there, and how to behave on returning home. This warning system is weekly published on websites of National Institute of Public Health and CHMI, Prague, over entire season (March–November).

*Key words: Ixodes ricinus* tick activity, prediction of attack risk level, warning system, TICKPRO computer program, tick-borne encephalitis

**Address for correspondence:** M. Daniel, National Institute of Public Health, Šrobárova 48, 100 42 Prague 10, Czech Republic. E-mail: midaniel@seznam.cz

## INTRODUCTION

Human infection with tick-borne encephalitis (TBE) virus and borreliae causing Lyme borreliosis (LB) depends on the attachment of an infected *Ixodes ricinus* tick which is the major vector of these zoonoses in Europe. In the Czech Republic, cases of possible TBE infection via the alimentary tract are rather sporadic (1). Since there exists no specific remedy for TBE, the most important protection (aside from vaccination) is targeted prevention which primarily includes the minimizing of the risk of being attacked by a tick. The level of that risk changes depending on weather conditions and their fluctuation on the seasonal as well as day-to-day scale. In the Czech Republic, TBE is a typical recreational-linked infection that is connected with outdoor activities. In the last decade (2000–2009), 6,429 laboratory confirmed human cases have been registered in the data base EPIDAT, National Institute of Public Health, Prague (NIPH). In 2006, there was an exceptionally sudden increase with 1,029 registered human TBE cases, the national incidence having reached 10/100,000 inhabitants (2).

Our aim was to create an objective warning system indicating the level of risk of attack by ticks in view of meteorological factors. In question wasn't an attempt to model the whole developmental cycle of *I. ricinus*, which is a long-term process influenced by a number of factors, but the formation of a program predicting host-seeking activity in the part of the tick population corresponding to that developmental stage.

It is based on the computer program TICKPRO (tick prognosis) producing a medium-range forecast (1–4 days) of five levels of the host-seeking tick activity, supplemented with recommendations how to prepare oneself and behave in terrain with possible occurrence of ticks and on returning home.

Each predicted level of risk requires the determination of the current proportion of ticks (of the total local population) that are in the host-seeking stage. Thus, the question involves relative data depending on local conditions (type of natural environment, altitude above sea level, etc.).

An important aspect of our endeavour was to transfer results of theoretical research into a practical form available and applicable by the lay public, as well as the public health services as a component of preventive measures. Materialization of that intention through the Internet proved to be a suitable means. We found no analogous project referring to *I. ricinus* ticks in the literature.

The prediction of host-seeking activity by *I. ricinus* is based on routine weather forecasts as produced by the forecast service of the Czech Hydrometeorological Institute (CHMI) implementing standard forecast methods, including numerical models produced by world prognostic centres. The program TICKPRO utilizes those data inputs.

## MATERIAL AND METHODS

This report is based on results of a study of the influence of changing weather on *I. ricinus* host-seeking activity carried out over the years 2001–2006 at three plots, each of 200 $m^2$, within the cadastre of the village Točná by Prague (14°24’55’’E; 49°58’42’’N; 330 m a.s.l.) in a typical *Querceto-carpinetum* habitat of tick occurrence, where the presence of TBE virus as well as Lyme-disease borreliae (*Borrelia burgdorferi* sensu stricto, *B. afzelii* and *B. garinii*) have been demonstrated in the study period (unpublished data). The occurrence of active ticks was evaluated using the flagging method once a week over the entire season (March – November). All developmental stages were counted separately. The ticks found were immediately returned to the plot being monitored after determining their species and developmental stage. Tick numbers from 2001–2003 samples formed the basis for the derivation of mathematical models; tick numbers registered later served for rectification and verification of the results of TICKPRO program (see relevant paragraph of the Results). There were counted correlation coefficients for: 1) the relationship between predicted and empirically found tick host-seeking activity, 2) the relationship between assessment of tick activity based on predicted and really measured meteorological factors, 3) relationship between prediction of activity resulting from the models based on precipitation factor on one side and relative air humidity factor on the other.

Data on TBE cases recorded on the Czech territory during the study period were obtained from the data base EPIDAT (NIPH, Prague).

Meteorological data were excerpted from records of the CHMI in Prague – Libuš, nearby. At that stage of research we had assessed the relation of a total of 22 meteorological factors (or combinations derived thereof) with the observed tick activity, expressed in mathematical equations, further on referred to as “models” (for details see [3]). We designated the term “activity” to describe host-seeking activity determined by the equation

$$a(M) = i_a/i_m$$

where $i_a$ designates the actual frequency of active ticks in the area, $i_m$ is the mean frequency of active ticks in the area under investigation computed over a longer period, at least one year. The two models that were selected were those that were most successful, and included meteorological factors that either are a component of standard weather forecasts or that may be deduced from these published data.

The first model selected [hereafter designated as Model 1 (Td+Rd)] implemented daily air temperature (average from temperatures at climatological observation times) and a daily sum of precipitation:

$$a(M) = \{f(T)+f(R)\}/2 * f(D).$$

The simple quadratic function of temperature is

$$f(T)= -0.00604*(Td)^2 +0.19955*(Td) – 0.3504;$$

where Td is the daily mean temperature.

The precipitation function is simple quadratic relation:

$$f(R) = -0.0031126*(R)^2 + 0.043644*(R) + 0.9981,$$

where R is the daily sum of precipitation.

The second model selected [hereafter designated as Model 2 (Td+RH)] was based on the temperature and relative air humidity (two meters above the ground) that is given by the equation:

$$a(M) = \{f(T)+f(RH)\}/2*f(D).$$

The simple quadratic function of temperature is the same as above.

The simple quadratic function of relative humidity is

$$f(RH) = -0.00075096*(RH)^2 + 0.085579*(RH) – 1.1906;$$

where RH is the daily mean relative humidity in %.

Seasonal changes in *I. ricinus* activity cannot be explained by only the influence of meteorological factors. Also important is the intrinsic factor f(D) (designated further on as “predisposition to activity” PRE_A) determined on the basis of follow-up of seasonal changes in tick occurrence on experimental fields. The intrinsic factor f(D) describes hostseeking activity as a phenologic characteristic of *I. ricinus*, determined by relationships between climate, seasonal variations, other ecological factors and the intrinsic life-history of the tick. The result is an idealized curve based on long-term field monitoring. TICKPRO program predicts the deviations (positive or negative) between daily values of the curve and the model estimates of host-seeking activity, based on routine weather forecasts.

The predisposition activity was derived by fitting of the forth polynomial to the all empirical activity data sorted by calendar datum (not seeing to the value of year) using the method of the least squares (the package STATISTICA 6 was practically used):

$$f(D)=PRE\_A=-12.972174+0.292968729*(D) -0.0019761*(D)^2 + 0.00000540961* (D)^3 -0.0000000053009*(D)^4$$

where D is ordinal number of day within year. The intrinsic factor f(D) is included in both of the models applied.

The preparation of the prognostic program was executed in following stages:

1. The creation of an original software computer program implementing the computer language BORLAND PASCAL, connecting forecasts of air temperature, relative humidity and precipitation with a consecutive calculation of predicted *I. ricinus* activity following the two models presented above. Of the input routine meteorological forecasts we applied: minimum air temperature (range of values); maximum temperature (range); characteristics of precipitation (6 categories); total precipitation (range); kind of precipitation; duration of sunlight; cloudiness; prevailing winds and velocity (average and maximum possible impact).

2. Testing of the program on the basis of the monitoring of ticks (in the years 2004 and 2005) at dates with selected synoptic situations described in successful weather forecasts that were available in the archives of forecasts at the CHMI. Tested was a total of 30 successful forecasts (half of them were 100% successful; the rest were at least 90% successful).

3. In 2006, tick monitoring was conducted season-long continuously in relation to our predictions of tick activity.

4. Final adjustments to the output of the TICKPRO program (i.e., determination of the level of risk of tick attack) were carried out in the course of 2007 and 2008 when the forecasts were being given to the public on a routine basis on the websites of the CHMI and NIPH.

5. In 2008, an analysis studied the correlation between the predicted level of the risk of tick attack and the registered TBE morbidity in the Czech Republic (taking into account the incubation period of the infection).

## RESULTS

### The TICKPRO Program

The computer program with the acronym TICKPRO, which facilitates medium-range forecasts of the level of host-seeking activity in ticks within a 1–4 day horizon has been elaborated. The program is based on the medium-range weather forecast routinely produced at the CHMI forecasting department, as well as on previously elaborated mathematical models (see Methods) describing the correlation of meteorological factors with the host-seeking activity of *I. ricinus*.

The relations between host-seeking activities of developmental stages of I. ricinus in the monitoring polygons and the values estimated from means of both models used in TICKPRO program were evaluated during 2001–2004 (Table 1). The category „larvae only“ is not included because of low correlation coefficients, where the level of significance fell between p=0.05 and p=0.10. Possibly the highly clustered field distribution of larval ticks is responsible. Also, the category "adults only" was not analyzed separately because of the low numbers of specimens monitored. The combination "adults plus nymphs" (NAd) gave better results than the category "nymphs only". This combination is used in TICKPRO program (see also below). Correlation coefficients were highly significant ($p<0.01$), for the category of all stages together (LNAd).

***Table 1.*** *An average correlation between host-seeking activity of Ixodes ricinus developmental stages based on the data empirically found in 2001–2004 and the activity estimated according to the Model 1(Td+Rd) and Model 2(Td+RH)*

| Stage/Year | Model 1(Td+Rd) | Model 2(Td+RH) |
|---|---|---|
| N 01 | 0.722 | 0.683 |
| N 02 | 0.878 | 0.875 |
| N 03 | 0.816 | 0.816 |
| N 04 | 0.807 | 0.836 |
| AVG | 0.806 | 0.802 |
| MAX | 0.878 | 0.875 |
| MIN | 0.722 | 0.683 |
| NAd 01 | 0.731 | 0.693 |
| NAd 02 | 0.877 | 0.874 |
| NAd 03 | 0.821 | 0.821 |
| AVG | 0.810 | 0.807 |
| MAX | 0.877 | 0.874 |
| MIN | 0.731 | 0.693 |
| LNAd 01 | 0.699 | 0.651 |
| LNAd 02 | 0.804 | 0.810 |
| LNAd 03 | 0.734 | 0.746 |
| LNAd 04 | 0.827 | 0.839 |
| AVG | 0.766 | 0.762 |
| MAX | 0.827 | 0.839 |
| MIN | 0.699 | 0.651 |

Td – daily mean temperature; Rd – daily mean rainfall; RH – daily relative air humidity; N – nymphs; NAd – nymphs + adults; LNAd – larvae + nymphs + adults; AVG – average; MAX – maximum; MIN – minimum.

The study of these models demonstrated the importance of separate analyses of the activity of larvae and nymphs, or nymphs together with adults. This information is significant because nymphs are the major stage attacking humans, whereby playing a very important role in the epidemiology of human infection. Below, we present values relating to the group of nymphs and adults together (marked NAd).

The program proceeds as follows:

1. Determination of forecast parameters – input of the calendar date of the first forecast day and selection of region (for a more exact forecast from a broader selection within the framework of the Czech Republic when it is a component of a meteorological forecast). Valid data extend from March 1 through November 30. Whenever the forecast calls for a continuous blanket of snow, the program cannot be applied.

2. Direct input of elements from the routine meteorological forecast (see Methods), and from these, calculation of factors that are a component of *I. ricinus* activity models but not provided directly by the meteorological forecasting service. The *I. ricinus* activity calculations include the average temperature calculated as the average from the mean for the minimum and the mean for the maximum temperature. In precipitation, the average of the daily total is applied. Further, the program estimates the near-ground temperature (5 cm from ground) and the dew point (5 and 20 cm from ground), these being necessary for the estimation of relative air humidity (RH). Besides the calculation of this quantity, the program allows for comparison (or correction) of the data on long-term territorial RH values for Bohemia and Moravia.

3. Automatic generation of verbal characteristics of expected weather.

4. Automatic calculation of *I. ricinus* activity following the models presented in Methods.

In view of the formal difficulties in the direct calculation of the 4th degree polynomial (intrinsic factor PRE_A) in the milieu of the programming language BORLAND PASCAL, the value of this factor is read from the auxiliary text file PRE_A.TXT counted in advance for each day of a year in Microsoft Excel using the 4th polynomial, based on the *I. ricinus* monitoring on the locality Točná.

5. Result depiction on the computer display and their loading in two files: RESULTS.TXT (entered content of screen suitable for publication – see Tab. 2); RES_STA.TXT (tabellar arrangement suitable for consequent statistical processing).

The predicted *I. ricinus* activity is also compared in these outputs with the expected probable value read from the file PRE_A.TXT (see above) for the given day of the year. The comparison is facilitated by expressing the differences in percentages.

6. Metaclassification of results in a five level scale of risk of *I. ricinus* tick attack. Results are published on the websites of the

**Table 2.** *A specimen of the computer display output (file RESULTS.TXT) of Ixodes ricinus host-seeking activity prediction*

| RESULTS OVERVIEW Tuesday 15. 8. 2006 Region: STR_C | | |
|---|---|---|
| Status of weather: HALF CLEAR SKIES, POSSIBILITY OF STORMS | | |
| Tick activity | Mean activity | 0.84955 |
| | Model 1 (Td+Rd) | 1.00781 |
| | Model 2 (Td+RH) | 1.09814 |
| Temperatures | maximum in 2 m (°C) | 21–26 |
| | minimum in 2 m | 13–9 |
| | surface (5 cm) | 5.2 |
| | dew point (2 m, 5 cm) | 8.6/14.7 |
| Vertical Precipitation | shape | local showers |
| | typical amount (mm) | 0–7 |
| Sunshine duration | hours | 12 |
| Wind | speed (m/s) | 3 gust: 7 |
| Cloudiness | eights | 2 |
| Air humidity | % | 59 |
| Alert | thanks to previous precipitation alleviation of drought of soil will continue | |

STR_C means “Middle-Bohemian region”; MEAN ACTIVITY means the value of the intrinsic factor (= activity predisposition PRE_A) of the day. Td – daily mean temperature; Rd – daily mean rainfall; RH – daily relative air humidity.

CHMI and NIPH in Prague, including brief instructions on how to behave in the situation of the predicted risk on visiting (and afterwards) the terrain with presumed *I. ricinus* tick occurrence (Table 3).

## Results of the Testing of the TICKPRO Program

In the years 2004 and 2005, in selected days (see Methods), we compared the empirically determined *I. ricinus* activity (by flagging monitored plots) with the activity prognosis generated by the TICKPRO program, as well as with its estimate based on actually measured meteorological values on the day of monitoring.

The comparison of empirically observed activity with the predicted activity is a measure of the success rate of forecasting, and at the same time is also a measure of the success rate of the models as such, working with the factors of precipitation [Model 1 (Td+Rd)] and of relative air humidity [Model 2 (Td+RH)]. In both years the former attained a correlation coefficient of 0.8255 and 0.8514; the latter, 0.7923 and 0.8232, respectively.

The “precipitation” model was thus somewhat more successful. Comparison of forecast versions with the version working with values of meteorological factors actually measured on the day of flagging revealed correlation coefficient values of 0.9962 and 0.9877, respectively for the “precipitation” model; and 0.9908 and 0.9668, respectively for the model working with RH of the air. At such high values the transition from actually measured meteorological factors to their predicted values does not diminish the success rate of the models applied. A mutual comparison of the forecast results following both models in 2004 approximated identity (0.9977), such similarity in 2005 being a bit weaker

**Table 3.** *Five levels of Ixodes ricinus attack risk prediction presented on websites and supplemented with brief recommendations for behavior on visits of tick habitats*

| | |
|---|---|
| 1<br>Low risk | Recommendation: Visiting deciduous woods and mixed growth and bushes with herbaceous vegetation, choose clothing made of smooth bright colored textile; moving about in the field inspect it from time to time (namely trousers) and remove possible ticks (the same is valid also in all other levels of risk). On return home, inspection of body in the evening as well as the following morning, immediately removing any tick. |
| 2<br>Moderate risk | Recommendation: Application of repellent; do not sit or lie in the vegetation in visited places. On return home, inspection of body in the evening as well as the following morning, immediately removing any tick. |
| 3<br>Considerable risk | Recommendation: Application of repellent; do not sit or lie in the vegetation in visited places, do not enter bushes, tall grass and herbal vegetation. On return home, inspection of body in the evening as well as the following morning, immediately removing any tick. |
| 4<br>High risk | Recommendation: Application of repellent; do not sit or lie in the vegetation in visited places; do not enter bushes, tall grass and herbal vegetation, namely at the edge of a wood, deciduous thickets and river banks. On return home, inspection of body in the evening as well as the following morning, immediately removing any tick. |
| 5<br>Very high risk | Recommendation: Do not enter freely deciduous and mixed woods, using only paved ways for moving about. On return home, inspection of body in the evening as well as the following morning, immediately removing any tick. |

(0.9801). All these correlation coefficients are highly significant at the 1% level: in 2004, p(0.01) = 0.6614; in 2005, p(0.01) = 0.6226.

In verifying the *I. ricinus* activity projection in 2006, correlation coefficients were computed for each day in which flagging was performed, disregarding the degree of success of routine weather forecasts. The result was coefficients of 0.7727 (in the "precipitation" model) and 0.7362 (in the RH model); p(0.05) = 0.3608. Furthermore, the *I. ricinus* activity forecast was gradually verified on application of meteorological forecasts 1–4 days older. For the 4th day, surprisingly, there were correlation coefficients of 0.7838 (precipitation model) and 0.7653 (RH model). The average of correlation coefficients (for 1–4 days) was 0.7797 (precipitation model) and 0.7501 (RH model); p(0.05) = 0.3608.

In 2008, when the forecasts of the tick activity in the Czech Republic were maintained in real time for the whole season, the verification of the prediction of *I. ricinus* activity was based on comparison of predictive statements on seeking activity with the evidence of tick-borne encephalitis in the Czech Republic using weekly incidence data (datum of first symptoms). Between April 4th and October 19th there were 87 predictions published, usually on Thursday and covering the interval Friday–Sunday. These data on awaited tick activity have been compared with the TBE incidence data of the same week, following week, third, fourth etc., finishing with the 15th future week. For each pair of rows shifted in this manner, correlation coefficients were computed. The tightness of the relation is significant in all cases and gradually grows from "no time lag" to the time lag of 5 and 6 weeks, and then rapidly decreases – see Table 4. The best result obtained for the time lag of 6 weeks indicates about 79% successfulness of predictions. The situations corresponding to "no time lag" and "time lag six" are depicted on Figs. 1 and 2.

In the first half of 2009 a marked increase in the incidence of TBE was recorded which exceeded 1.4 times the value for the same period of the preceding year and 1.7 times the ten-year average for the Czech Republic (4). This situation which indicates the extraordinary character of the season in 2009 (characterized by a massive and early spring-summer peak of TBE incidence) was predicted with the aid of the TICKPRO program. For that season the program indicated continuously higher values (up to by 23% except for weeks 23 and 28) than the six-year average of

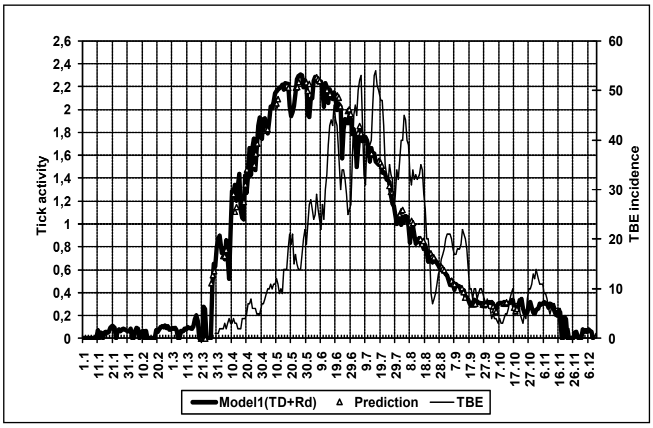


***Fig. 1.** Predicted Ixodes ricinus host-seeking activity in correlation with tick-borne encephalitis incidence (no time lag used; r = 0.4047). Czech Republic, 2008. Tick activity computed from actual meteodata as Model 1 (Td+Rd) (thick black line), predicted on the same principle using meteorological 3 day forecast (triangles) and TBE incidence (TBE, 7 day sums, step 1 day – thin black line). The correlation coefficient is r = 0.4047; it is highly significant, but substantially less than the one for time lag 6 weeks.*

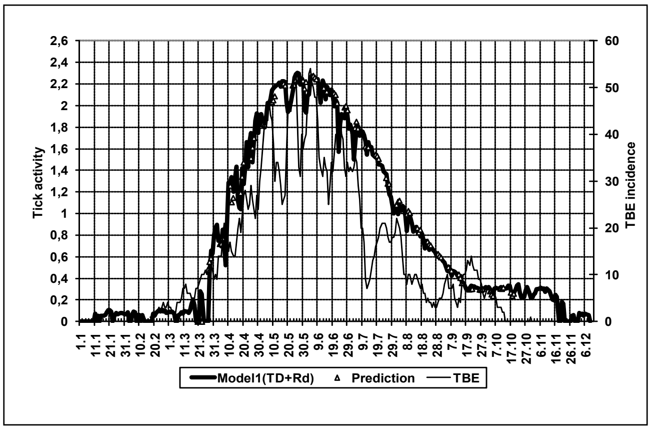


***Fig. 2.** Predicted Ixodes ricinus host-seeking activity in correlation with tick-borne encephalitis incidence (time lag 6 weeks; r = 0.8870). Czech Republic, 2008. Tick activity computed from actual meteodata as Model 1 (Td+Rd) (thick black line), predicted on the same principle using meteorological 3 day forecast (triangles) and TBE incidence (TBE, 7 day sums, step 1 day – thin black line). The correlation coefficient r = 0.8870; it is highly significant: p (0.001) = 0.3411 and means practically 78.7% probability of the prediction.*

***Table 4.** Relation between forecast of tick activity and occurrence of tick-borne encephalitis human cases in the Czech Republic (2008) given by the correlation coefficients (r). All values are significant at level of 0.1% (p 0.001=0.34107)*

| Time lag (weeks) | r | Time lag (weeks) | r |
|---|---|---|---|
| 0 | 0.404680 | 8 | 0.800527 |
| 1 | 0.559499 | 9 | 0.726490 |
| 2 | 0.675264 | 10 | 0.650210 |
| 3 | 0.781379 | 11 | 0.584224 |
| 4 | 0.859375 | 12 | 0.533098 |
| 5 | 0.886443 | 13 | 0.415213 |
| 6 | 0.886984 | 14 | 0.404539 |
| 7 | 0.858512 | 15 | 0.340799 |

host-seeking activity monitored in comparable weeks in the field. The relationship of the predicted values and TBE case incidence in each week of 2009 is demonstrated in Fig. 3, in which we applied a 3-week time lag of the prediction of the development of the disease from the time of attack by the infected tick to the appearance of initial symptoms. (The temporal shift has to be considered with a tolerance of one week in view of the weekly values of registered cases.) The predicted value of *I. ricinus* host-seeking activity in the Fig. 3 is an average of three-day values of weekend prediction prior to the week of registered cases and is expressed as the percentage of the deviation from the six-year average of activity calculated individually for each calendar day

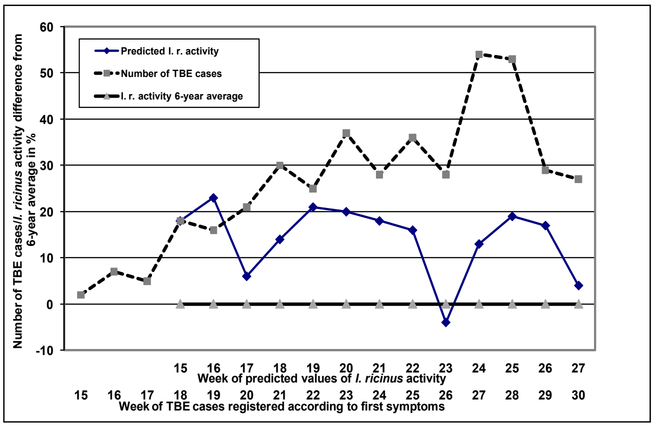


***Fig. 3.*** *The predicted host-seeking activity of Ixodes ricinus compared with TBE incidence registered according to initial disease symptoms in each week of the first half of the year 2009 in the Czech Republic.*

*The temporal shift by 3 weeks takes into account the time since attack by infected tick to the initial symptoms of disease. The predicted activity is expressed in percentages of deviation from the six-year average host-seeking activity found in monitoring in the field calculated for each day.*

*Axis x: Upper line – weeks of predicted I. ricinus host-seeking aktivity. Lower line – weeks of registered TBE cases according to initial symptoms of disease.*

*Axis y: Numerical values common for both represented quantities: number of TBE cases and difference of predicted I. ricinus activity from the six-year average, based on monitoring in the field, in %.*

of the prediction made. The relation of the graphically compared quantities is clear and documents the practical applicability of the TICKPRO program not only as a component in the preventive warning of the population, but also as a prognosis of the development of the TBE epidemiological situation in general.

We assume that the shorter time lag needed for demonstrating the relation of the predicted host-seeking activity and initial symptoms of TBE than has been stated in the preceding year (2008) in the statistical analysis of the annual total of registered TBE cases reflects the explosive increase of cases in the spring-summer period of maximum TBE incidence in 2009. In a separate assessment of the values of predicted *I. ricinus* activity with the aid of both models that are components of the TICKPRO program it can be stated that moderately higher values were attained using the precipitation model in comparison with the model based on the relative air humidity (the RH model), that being comparable with previous results (see above).

## DISCUSSION

The parasitic phase of life in relatively lengthy development of *I. ricinus* is temporally very limited while most time its development takes place free in vegetation or in humicolous or edaphic conditions in which it is very exposed to meteorological factors. In general, in question is long-term action (including inter-annual seasonal changes) that influences all stages of development (including oogenesis, embryogenesis and all the degrees of metamorphosis) as well as short-term (diurnal) changes in weather that highly influence the part of the population physiologically mature for host-seeking activity. The quantitative ratio of the host-seeking cohort to the whole tick population is influenced to a certain degree by the season of the year (the TICKPRO program counting with that by including the intrinsic factor) not with the local abundance of ticks. The latter is clearly conditioned foremost by a suitable habitat, the presence of hosts for each developmental stage, long-term climatic conditions, and in line with them also the geographic location. The idea, that one can prepare a dynamic model (including all the qualitative as well as quantitative conditions) generally valid for the whole area of *I. ricinus* distribution, is therefore only hypothetical. Problems of modelling tick-borne zoonoses are analysed in an extent review (5). Climate changes observed in the last decades and the synchronous upsurge the incidence of TBE (as well as other tick-borne diseases) has attracted great attention, and resulted in an effort to create predictive models. For recent overviews see 6 and 7. Generally, the description of epidemiological reality and practical applications in public health are the problems with model development.

In the collection of background data we include all available elements measured by the meteorological service (and their possible combinations) that can be assumed to have potential influence on *I. ricinus* host-seeking activity. Taken into consideration was also the hypothetical contemplation on the influence of photoperiodicity the potential influence of which would be seasonal in a standard way and so introduced in the TICKPRO program within the frame of the intrinsic factor. Short-term changes in the intensity of daylight in our basic analysis were represented by the daily numbers of hours of sunlight, however, always with insignificant results. During the first years 2001–2003 our research was designed to answer the following questions: 1. Is the relationship between daily weather conditions and tick behaviour close enough to be used for the prediction of tick host-seeking activities and thus for the prediction of human TBE infection risk? 2. Can meteorological data provided by standard meteorological network be used to estimate tick activities? Both questions have been answered successfully. The relationship between the daily activities *I. ricinus* and weather conditions can be described using 2- to 3-parameter models. Our studies demonstrate that the relationship between weather and tick behaviour is solid enough to be used for the prediction of tick host-seeking activity from spring to autumn, for the prediction of the risk of tick attacks and thus for the prediction of TBE virus infection risk of people visiting natural foci of the disease. The accuracy of such predictions is determined by the reliability of weather forecasts produced by the public meteorological services. The regional validity of weather forecasts determinates regional validity of the predictions of tick host-seeking activity.

It was necessary to prove the close relationship between essential meteorological factors and tick host seeking activity on individual sites, in order to overcome the influences of other environmental factors, and to be as near as possible to the source of the pertinent meteorological data. The locality Točná has satisfied those conditions. The relationship is applicable for the entire area in which the standard weather forecast is applicable.

The TICKPRO program applies routine meteorological forecasting, and its success rate therefore depends on the accuracy of those forecasts. The tests performed demonstrate a success rate of over 68% (measured as the product of the success rate of routine meteorological forecasting and calculation of *I. ricinus* activity on the basis of meteorological data). Its application has certain limitations. The program is designed for the period from March 1 through November 30 (except for days with a complete blanket of snow). That, of course, does not exclude the sporadic occurrence of active ticks (and thereby risk of tick attack) in rather exceptional meteorological conditions in the winter season (e.g. the winter of 2006/2007 – see 8).

Practical outputs are relative levels the risk of *I. ricinus* attack, derived from the output of the computer program. Their value (expressed in the absolute number of active ticks per unit of area) is variable according to local environmental conditions; namely, to habitat and altitude a.s.l. Documentation applied for the construction of models describing the influence of meteorological factors on *I. ricinus* activity and the calculation of the intrinsic factor are derived from the monitoring of ticks in an area characterized by optimum conditions for the occurrence of *I. ricinus* ticks in the territory of Bohemia. It includes suitable environmental conditions including habitat, microrelief, altitude, presence of game animals (roe deer) regulated according to hunting and game management rules, and also presence of TBE virus and Lyme borreliosis genospecies. (See also Material and methods.)

Validity of the prognosis could be modified by some regional differences, mainly landscape characteristics (absence of suitable habitats for ticks) and by altitude. From this standpoint, predictions developed using TICKPRO program can be characterized as "very accurate" in areas with suitable habitats up to an altitude of 700 m above sea level, versus "reasonably accurate" in higher altitudes. The major types of hazardous habitats are presented on corresponding websites in the commentary accompanying the results of the prognosis. Detailed information on habitats under risk on Czech territory is supplied in the Atlas of Prediction Maps (9).

Formally, it is possible to make a forecast for up to 8 days. In view of the gradually diminishing success rate of the meteorological forecast with each successive day in the forecast, it is meaningful to expect only 3- to 4-day forecasts. The results of tests in 2006 verifying the validity of prognoses have demonstrated their four-day usefulness.

Forecasts performed by the TICKPRO program estimate the degree of *I. ricinus* host-seeking activity regardless whether an animal host or a human being is in question. In the application of results in human infection epidemiology, another factor has to be considered – human activities. In the Czech Republic, TBE is a markedly recreation time linked infection connected with out-door activities that are likewise influenced by weather conditions to a great degree (2). Another factor in play is, of course, the prevailing rate of tick-borne pathogens in ticks.

Taking into consideration all the factors mentioned, we have attempted to determine the relationship between *I. ricinus* activity forecasts and TBE morbidity, in order to verify the practical impact of the presented prognoses. At that, the time lag between the presumed attachment of the tick (the date of the materialized prediction) and the manifestation of initial symptoms of TBE must be taken into account. In the literature the incubation period is said to be from 3 to 28 days (10). The correlation produced positive results, with growing significance from the third week with a maximum in the 5th and 6th weeks (see Table 4). That result does not necessarily mean that the length of incubation was being underrated up to now. Rather, in most of the reported cases, neurological symptoms have probably been recorded as being the first symptoms for which the patient was hospitalized, disregarding the first stage of a influenza-like affection (1st week) and consequent relief (2nd week). Similar time lag values have also been found in the determination of the correlation between changing meteorological conditions and TBE morbidity in the Czech Republic in the decade of 1994–2004 (11, 12).

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