EFFECT OF ENVIRONMENTAL VARIABLES ON INCIDENCE OF TICK-BORNE ENCEPHALITIS, LEPTOSPIROSIS AND TULARAEMIA

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SUMMARY

Objectives: Potential effect of three environmental variables (population density of rodents, global weather in the form of the North Atlantic Oscillation (NAO) index, and acorn crop) on human morbidity rate of three zoonoses: tick-borne encephalitis (TBE), leptospirosis and tularaemia were analysed in the Czech Republic for the period 1970–1990.

Methods: The Pearson's correlation analysis was used.

Results: The correlation analysis revealed that the significant factor for explaining annual morbidity rates of these zoonoses was the abundance of common voles (*Microtus arvalis*) in the current year (for leptospirosis) or in the previous calendar year (for TBE and tularaemia).

Conclusions: The two other environmental variables tested (NAO index and acorn production) do not seem to play a significant role in these zoonoses in Central Europe.

Key words: Czech Republic, rodents, Microtus arvalis, Flavivirus, Leptospira, Francisella, North Atlantic Oscillation, acorn crop

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INTRODUCTION

Three zoonoses important in Central Europe were selected for the study: tick-borne encephalitis (TBE) caused by flavivirus, leptospirosis caused by *Leptospira interrogans* (most reported infections are due to serovar grippotyphosa in the Czech Republic), and tularaemia caused by *Francisella tularensis holarctica*. For these zoonoses, reservoir or host vertebrates are rodents, but the mechanisms of human infection differ. While for leptospirosis it is a direct (or indirect via water contaminated by rodents) contact with rodents; TBE is characteristically transmitted by ixodid ticks; and tularaemia by diverse routes – direct or indirect contact with infected mammals such as hares or rodents, less frequently also by bites of ixodid ticks, ingestion of contaminated food or water, aerosol, etc. (1).

In the present study, potential effect of several environmental variables on the incidence of these zoonoses was analysed, namely the effect of annual population size of the common vole (*Microtus arvalis*), global weather expressed in the form of the North Atlantic Oscillation (NAO) indices, and volume of acorn (*Quercus spp.*) crop.

The NAO system is the major mode and cause of global weather and climate fluctuation affecting Northern and Central Europe (2). The NAO indices are based on normalized sea-level pressure differences between Ponta Delgada (Azores) and Stykkisholmur/Reykjavik, Iceland. The positive NAO index means that the atmospheric pressure over the subtropical part of the North Atlantic is higher than normal while that over the northern sector of the North Atlantic is lower than normal; this increased pressure difference between the two sectors results in more and stronger storms crossing the Atlantic Ocean and, in turn, causes warm and wet weather (especially in winter) in Northern and Central Europe. The negative NAO index reflects an opposite pattern of height and pressure anomalies over these sectors; this reduced pressure gradient results in fewer and weaker storms crossing the Atlantic Ocean, bringing cold air to Northern and Central Europe.

MATERIALS AND METHODS

A long-term (1970–1990) annual morbidity rates (human cases per 100,000 inhabitants) of TBE, leptospirosis and tularaemia in the Czech Republic were compared with annual population size of the common vole using also shift of the disease morbidity for one and two next calendar years. In parallel, potential effect of global weather expressed in the form of the annual NAO index and annual acorn production were tested.

Annual morbidity rates of human TBE, leptospirosis and tularaemia in the Czech Republic for the years 1970–1990 were released by the National Institute of Public Health, Prague, in the national database EPIDAT of notifiable diseases.

Estimates of the common vole (*Microtus arvalis*) annual population size (relative abundance) in the Czech lands were based on data of the Czechoslovak State Phytosanitary Institute, Prague. Log counts of the rodents were extracted from reports on annual

density of active burrows (re-opened entrances per hectare) of common voles in 71 Czech districts in the period 1970–1988 and averaged (weighted according to size of human population in individual districts); these data were supplied by Prof. E. Tkadlec.

Annual data on acorns crop (in kg) in the Czech lands were published in the Statistical Yearbooks of the Czechoslovak Republic, 1970–1988. Annual and winter NAO indices for the years 1970–1988 were extracted from particular website*.

All data are given in Table 1. Statistical analysis used Pearson's correlation coefficient r (calculated with the Excel statistical programme) as a measure of coincidence between variables; the level of significance of the null hypothesis was at $p < 0.05$.

Table 1. *Annual data of environmental variables (voles, acorns, NAO) and morbidity (cases per 100,000 inhabitants) of tick-borne encephalitis (TBE), leptospirosis and tularaemia in the Czech Republic*

Year	Vole population size*	Acorn crop (kg/year)	NAO annual index	TBE	Leptospirosis	Tularaemia
1970	6.130	232,655	−1.08	5.120	0.938	0.541
1971	6.865	885,808	−0.08	3.109	2.303	0.632
1972	6.084	40,236	+2.05	3.198	1.722	0.557
1973	6.061	741,503	+0.27	5.059	0.683	0.171
1974	5.906	33,374	+2.18	3.960	1.277	0.090
1975	6.203	834,639	+0.01	3.758	1.800	0.239
1976	5.360	329,866	+0,59	3.682	0.364	0.315
1977	5.781	68,603	−2.08	3.033	0.803	0.029
1978	6.957	17,336	−0.42	1.494	1.383	0.391
1979	5.177	189,577	−0.23	6.073	0.447	2.410
1980	5.723	111,864	−1.58	2.266	0.629	0.224
1981	6.502	152,705	−0.55	1.359	1.880	1.243
1982	5.142	md	+2.63	3.374	0.369	0.902
1983	6.447	248,027	+0.38	1.666	0.959	0.349
1984	5.611	346,630	+2.17	3.098	0.726	0.387
1985	5.779	164,600	−3.09	3.386	0.716	0.223
1986	5.613	680,416	+3.14	3.221	0.618	0.551
1987	5.654	20,043	−3.01	1.721	1.372	0.213
1988	6.188	270,483	−0.13	1.845	1.900	0.271
1989				1.603	0.983	0.328
1990				1.862	0.337	0.251

*Log counts active burrows – based on data of the Czechoslovak State Phytosanitary Institute, Prague; md – missing data; NAO – North Atlantic Oscillation

Table 2. *Correlation analysis (Pearson's coefficient values) of TBE, leptospirosis and tularaemia annual morbidity rates in the period 1970–1990 vs. annual relative abundance of common voles, annual North Atlantic Oscillation index, and acorn yield in the Czech Republic, 1970–1988*

Morbidity – shift of calendar year (Y):		Y	Y + 1	Y + 2
Tick-borne encephalitis	Vole abundance	+0.441	**+0.578**	+0.257
	NAO index	+0.169	+0.167	+0.060
	Acorn crop	+0.285	−0.025	+0.153
Leptospirosis	Vole abundance	**+0.756**	−0.080	−0.291
	NAO index	−0.098	−0.170	+0.066
	Acorn crop	+0.173	−0.020	+0.258
Tularaemia	Vole abundance	−0.237	**+0.546**	−0.344
	NAO index	+0.127	−0.288	−0.314
	Acorn crop	−0.030	−0.306	−0.324

Numbers in bold indicate significant values ($p < 0.05$); NAO – North Atlantic Oscillation

*http://www.cru.uea.ac.uk/cru/data/nao.htm

RESULTS

In the period 1970–1990 in the Czech Republic, the annual morbidity rate (per 100,000 inhabitants) of TBE, leptospirosis and tularaemia varied from 1.36 to 6.07 (avg. 3.04), from 0.36 to 2.30 (avg. 1.10), and from 0.09 to 2.41 (avg. 0.49), respectively. The results of the correlation analysis for the three zoonoses are presented in Table 2. In these zoonoses, statistically significant positive association between morbidity rate and tested environmental variables was only found for population size of the common vole, either in the current year Y (leptospirosis: r=+0.756) or in the previous calendar year (TBE: r=+0.578; tularaemia: r=+0.546) (Fig. 1). The results imply that 57% of the variability in leptospirosis or 33% and 30% of the variability in TBE and tularaemia, respectively, were explained (r^2) by the vole relative abundance in the same or in the previous calendar year. On the other hand, no significant correlation was found in this study between morbidity rate of the three zoonoses and either global weather (both annual and winter NAO indices) or acorn crop in corresponding or shifted years.

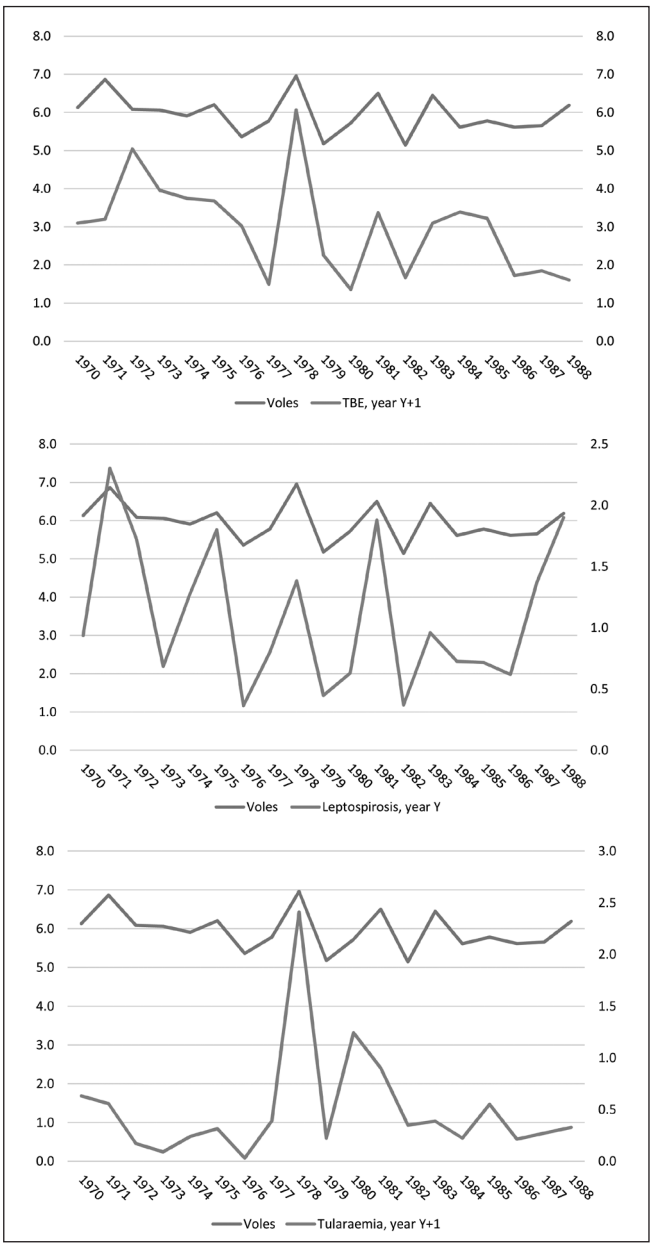

Fig. 1. *Correlation between population size of the common vole (upper line) and morbidity rate of tick-borne encephalitis, leptospirosis and tularaemia (lower lines).*

DISCUSSION

In an earlier study based on more extensive data (3), we also failed to demonstrate a significant correlation between global weather (NAO) and morbidity rate of human TBE and tularaemia in the Czech lands. However, leptospirosis incidence in that study revealed significant negative correlation with NAO when the morbidity rate was shifted for one or two calendar years.

There are marked epidemiological differences among the zoonoses tested. While leptospirae can be transmitted from rodents to man directly (basically a rodent-borne disease) or indirectly via water contaminated with infected rodents, TBE is a tick-borne disease mediated by ixodid ticks which have been infected themselves during the previous life stage (as a larva or a nymph) while feeding on a virus-bearing rodent. The transmission process is therefore protracted in tick-borne diseases and this is the reason why an enhanced TBE risk for humans occurs one year after an increased population density of rodents, the main hosts for preimaginal ticks. In tularaemia, human infections in Central Europe are characterized by seasonal dynamics: most cases occur very late in the year (December) but involve also January and February months of the next calendar year (human infections might occur during hunting seasons on hares). Therefore, any effects of environmental variables on reported human cases of tularaemia are to be reflected the next calendar year.

The common vole is known as a principal vertebrate host and reservoir of *Leptospira interrogans* serovar grippotyphosa (1). However, to the author's knowledge, quantitative data about the association of leptospirosis with the abundance of small rodents or global weather have not been published in Central Europe.

For TBE, Czech parasitologist Oto Havlík was the very first who recorded and described that "mice years" (overpopulation of wild mice) in Central Europe are followed by increased incidence of TBE in humans the next calendar year (4, 5). The same conclusion was reached in a recent study (6). Small rodents (in Central Europe especially *Apodemus spp.*, *Myodes glareolus* and also *Microtus arvalis*) are namely principal hosts of larval and nymphal *Ixodes ricinus* vector ticks and also amplifying hosts of TBE virus. Increased population density of rodents (including voles) makes possible their higher parasitisation by preimaginal *I. ricinus* ticks and thus a growing number of ticks infected with TBE virus (5).

Positive correlation between the abundance of forest rodents (especially *Myodes*) and density of infected *Ixodes persulcatus* ticks in the previous year was demonstrated in Perm Region, Russia, during long-term studies (1992–2001) on Lyme borreliosis (LB), another typical tick-borne infection (7). Also in the USA, the strongest predictors of the annual risk of LB were the prior year's abundance of rodents (*Peromyscus leucopus* mice and *Tamias striatus* chipmunks) with a partial effect of acorn crop two years previously, while the climate had only a weak effect (8). Interestingly, the correlation in human morbidity rate between TBE and LB in the Czech Republic was very high during the

period 1988–2006: the Pearson's coefficient value between the two zoonoses was $r=+0.821$ ($p<0.001$), based on the EPIDAT data and calculations of the author. In both diseases, the principal vector is the tick *I. ricinus* and the main amplifying/reservoir hosts are rodents. Therefore, the factors affecting incidence of these two tick-mediated diseases should be very similar, as it was shown in a recent paper (6).

CONCLUSION

An overpopulation of the common vole *Microtus arvalis* might indicate an increased human morbidity rate of leptospirosis in the same calendar year as well as that of TBE and tularaemia in the next calendar year in Central Europe. In this way, the size of the common vole population might contribute to prediction of leptospirosis, tularaemia and TBE (and most probably of LB, too) morbidity rate in humans.

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Conflict of Interests

None declared

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