Ecology of brucellosis of the European hare in the Czech Republic

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ABSTRACT: A geographic information system was used for the analysis of ecological conditions of distribution of natural foci of brucellosis in the European hare (*Lepus europaeus*) and their long-term persistence in the Czech Republic. The European hare is a reservoir host of *Brucella suis* biotype 2. A close correlation was found between the geographic distribution and numbers of natural foci of brucellosis in the Czech Republic in 1971 to 1985 and 1986 to 2000 ($r = 0.65$, $n = 814$, $P = 0.01$). Natural foci of brucellosis were persistent, but not stationary, over the period of 30 years. Natural foci of brucellosis were most abundant in habitats of beech forests and the mosaic of fields and forests ($x_b = 3.19$ and 2.95, respectively), geographic areas of 201–400 m of elevation above sea level ($x_b = 2.53$), 0.0–2.0°C of mean annual air temperature ($x_b = 3.62$), 1 401–1 800 mm of mean annual precipitation ($x_b = 4.52$), 1 601–1 800 h of mean annual sunshine duration ($x_b = 2.64$), and areas of the European hare population density of 51–100 individuals per 10 km^2 ($x_b = 3.33$). Natural foci of brucellosis seem to be independent of the population density of European hare.

Keywords: *Brucella suis* biotype 2; geographic distribution; long-term persistence; habitats; ecological conditions

Brucella species are obligate parasites having a preferred natural host that serves as a reservoir of the infection (Quinn et al., 1994). Infections by *Brucellae* have been found worldwide in a great variety of terrestrial wildlife species as well as a wide variety of marine mammals. It is important to distinguish between a spillover of infection from domestic animals and a sustainable infection in wild species (Godfroid, 2002). Some countries are considered to be officially brucellosis-free thanks to eradication programmes and monitoring. Wild animals, however, can be reservoirs of brucellosis and sources of infection for domestic animals and humans (Szulowski and Pilaszek, 2000). The European hare (*Lepus europaeus*) and potentially the wild boar (*Sus scrofa*) are reservoirs of *Brucella suis* biotype 2 (Garin-Bastuji and Delcueillerie, 2001; Hubalek et al., 2002), which is considered to be non-pathogenic to humans. There is, however, a report of infection of a farmer by this biotype (Teyssou et al., 1989). As a disease occurring in natural foci, it has a bi-component character spreading from one host to another by direct or indirect contact. Regarding this fact, the European hare brucellosis can be studied with respect to the host population density, ecological factors and types of habitats in the natural foci as well as long-term persistence in a given territory.

The aim of the study was to analyse the distribution of natural foci of brucellosis in the European hare in the Czech Republic on a quantitative basis using a geographic information system.

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MATERIAL AND METHODS

Selected aspects of ecology of natural foci of brucellosis were evaluated using computer geographic databases on the spatial distribution of ecological factors including the following maps:

1. Habitat distribution in the Czech Republic including (a) field biotopes, (b) alluvial forests, (c) oak forests, (d) mixed forests of beech, oak and fir, (e) beech forests, (f) the mosaic of fields and forests, (g) mountain and lower mountain mixed forests, (h) mountain spruce forests, and (i) mountain scrub pine forests.
2. Hypsometric geographic map of the Czech Republic divided into areas characterised by the elevation above sea level less than 200, 201–400, 401–600, 601–800, 801–1 000, and more than 1 000 m.
3. Mean annual air temperature map of the Czech Republic divided into categories of more than 10.0, 8.1–10.0, 6.1–8.0, 4.1–6.0, 2.1–4.0, and 0.0–2.0°C.
4. Mean annual precipitation map of the Czech Republic divided into areas characterised by precipitation levels of 450–700, 701–1 000, 1 001–1 400, and 1 401–1 800 mm.
5. Sunshine duration map of the Czech Republic divided into areas characterised by the mean annual sunshine lasting less than 1 600, 1 601–1 800, 1 801–2 000, and 2 001–2 200 hours.

The above-mentioned databases representing 50-year mean values of the above-listed ecological factors were already described (Pikula and Beklova, 1987; Pikula et al., 2002, 2003).

6. Database containing the mean spatial distribution of natural foci of brucellosis in the European hare in the years 1971 to 2000 in the Czech Republic. Source data were acquired from the Monthly Reports on Infectious Diseases in Animals issued by the State Veterinary Administration of the Czech Republic and saved as a map of mean numbers of natural foci of brucellosis in unit areas of the database during the 30-year study period. The above data were also divided into two geographic databases on the distribution and mean numbers of natural foci of brucellosis in the Czech Republic in the period of 1971 to 1985 and 1986 to 2000.
7. Database containing the mean spatial distribution of the European hare population throughout the Czech Republic. This geographic database was divided into areas where the European hare population amounted to the density of 1–50, 51–100, 101–150, 151–200, 201–250, and more than 250 individuals per 10 km^2, on average, in the long-term perspective of 30 years. Source data were acquired from bag records published from statistical data of the Ministry of Agriculture of the Czech Republic. For a description of this database cf. Pikula (1996).

Analytical tools of the KORMAP GIS program (Pikula and Beklova, 1987; Pikula, 1996; Pikula et al., 2002, 2003) were employed to evaluate statistically the ecological conditions of natural foci of brucellosis and their geographic distribution in the Czech Republic. The whole territory of the Czech Republic was divided into 1 814 unit areas characterised by the above-mentioned specific conditions. The distribution and numbers of natural foci of brucellosis in these unit areas of 5.1 × 8.5 km were checked against databases of the above-mentioned ecological factors to obtain frequency tables, from which we computed the mean number of natural foci of brucellosis (x_b) in a specific area. For these purposes the 30-year-period means of geographic distribution of brucellosis were used. The frequency table was further used to compute the coefficient of correlation between the two variables related. Differences in the variance of samples of numbers of natural foci in specific areas of environmental factors were tested by *F*-test. Statistical significance of at least $P = 0.05$ was accepted in testing the differences and correlation.

RESULTS

1. Long-term persistence of natural foci of brucellosis in the European hare in the Czech Republic. A close correlation was found between the geographic distribution and numbers of natural foci of brucellosis in the Czech Republic in the period of 1971 to 1985 and 1986 to 2000 ($r = 0.65$, $n = 1814$, $P = 0.01$). Natural foci of brucellosis persisted in quite the same geographic area during the period of 30 years.

2. Relation of natural foci of brucellosis in the European hare to various ecological factors. Results on the mean numbers of natural foci of brucellosis (x_b) in relation to habitats, elevation above sea level, mean annual air temperature, mean annual precipitation, mean annual sunshine duration, and European hare population density are summarised in Tables 1–6. Natural foci of brucellosis

Table 1. Relation of natural foci of brucellosis to various habitats

Habitats	x_b	n	S.D.
Field biotopes	2.03	569	4.97
Alluvial forests	0.48	25	0.71
Oak forests	1.41	293	4.62
Mixed forests of beech, oak and fir	0.76	103	3.53
Beech forests	3.19	324	7.31
Mosaic of fields and forests	2.95	327	6.84
Mountain and lower mountain mixed forests	2.24	118	4.35
Mountain spruce forests	2.64	38	4.43
Mountain scrub pine forests	0.00	17	0.00

x_b = mean numbers of natural foci of brucellosis in a specific habitat; n = number of unit areas evaluated; S.D. = standard deviation

Table 2. Relation of natural foci of brucellosis to the elevation above sea level

Specific areas characterised by the elevation above sea level	x_b	n	S.D.
Less than 200 m	0.47	120	0.84
201–400 m	2.53	552	5.83
401–600 m	2.43	687	6.63
601–800 m	1.89	345	4.36
801–1 000 m	2.36	77	4.61
More than 1 000 m	2.35	33	3.81

x_b = mean numbers of natural foci of brucellosis in a specific habitat; n = number of unit areas evaluated; S.D. = standard deviation

Table 3. Relation of natural foci of brucellosis to the mean annual air temperature

Specific areas characterised by the mean annual air temperature	x_b	n	S.D.
Higher than 10.0°C	0	5	0
8.1–10.0°C	1.77	403	3.88
6.1–8.0°C	2.33	1 115	6.41
4.1–6.0°C	2.38	257	4.61
2.1–4.0°C	2.88	30	4.06
0.0–2.0°C	3.62	4	7.25

x_b = mean numbers of natural foci of brucellosis in a specific habitat; n = number of unit areas evaluated; S.D. = standard deviation

Table 4. Relation of natural foci of brucellosis to the mean annual precipitation

Specific areas characterised by the mean annual precipitation	x_b	n	S.D.
450–700 mm	1.78	1 217	5.41
701–1 000 mm	3.00	490	6.13
1 001–1 400 mm	3.39	85	5.38
1 401–1 800 mm	4.52	22	6.39

x_b = mean numbers of natural foci of brucellosis in a specific habitat; n = number of unit areas evaluated; S.D. = standard deviation

Table 5. Relation of natural foci of brucellosis to the mean annual sunshine duration

Specific areas characterised by the mean annual sunshine duration	x_b	n	S.D.
More than 1 600 hours	0.24	160	0.43
1 601–1 800 hours	2.64	905	6.41
1 801–2 000 hours	2.16	738	5.21
2 001–2 200 hours	0.18	11	0.40

x_b = mean numbers of natural foci of brucellosis in a specific habitat; n = number of unit areas evaluated; S.D. = standard deviation

Table 6. Relation of natural foci of brucellosis to the mean spatial distribution of the European hare population throughout the Czech Republic expressed as areas characterised by the population density of 1–50, 51–100, 101–150, 151–200, 201–250, and more than 250 individuals per 10 km^2, on average, in the long-term perspective of 30 years

Specific areas characterised by the European hare population density (individuals per 10 km^2)	x_b	n	S.D.
1–50	2.96	196	4.57
51–100	3.33	251	6.75
101–150	2.27	505	6.86
151–200	2.36	463	5.58
201–250	1.40	165	4.17
More than 250	0.60	234	1.42

x_b = mean numbers of natural foci of brucellosis in a specific habitat; n = number of unit areas evaluated; S.D. = standard deviation were most abundant in habitats of beech forests and the mosaic of fields and forests (x_b = 3.19 and 2.95, respectively), geographic areas of 201–400 m of elevation above sea level (x_b = 2.53), 0.0–2.0°C of mean annual air temperature (x_b = 3.62), 1 401 to 1 800 mm of mean annual precipitation (x_b = 4.52), 1 601–1 800 h of mean annual sunshine duration (x_b = 2.64), and areas of the European hare population density of 51–100 individuals per 10 km^2 (x_b = 3.33). There is no correlation between the numbers of natural foci of brucellosis and the European hare population density in specific geographic areas (brucellosis seems to be independent of the population density of European hare). Testing the variance of the highest x_b-value sample against all the remaining categories of an individual ecological factor (i.e. within Tables 1–6) resulted in finding statistically significant differences (P = 0.05 and 0.01, respectively). Thus it can be stated that natural foci of brucellosis are bound to specific conditions.

DISCUSSION

One of the basic concepts of landscape epidemiology mentions the long-term persistence of the disease in distinct geographic areas (Pavlovsky, 1964). In this respect brucellosis of the European hare belongs to the category of diseases of natural nidality because according to our results it persisted in quite the same area in the Czech Republic during the years 1971 to 2000 and a close correlation was found between the geographic distribution and numbers of natural foci of brucellosis of the European hare in the Czech Republic in 1971 to 1985 and 1986 to 2000 (r = 0.65, n = 1814, P = 0.01).

It is an interesting fact that natural foci of brucellosis seem to be independent of the population density of European hare. It contrasts with the general view on infectious diseases and e.g. with the study analysing the population density and geographic distribution of the European hare (*Lepus europaeus*) under different ecological conditions in relation to natural foci of tularaemia in the Czech Republic (Pikula, 1996) and finding that the occurrence of tularaemia in the Czech Republic is dependent on the European hare population density with high statistical significance of correlation (r = 0.4431, n = 395, P = 0.01). The higher the population density of the European hare, the higher the number of natural foci of tularaemia in a given area. Considering the natural foci of tularaemia in the Czech Republic and another reservoir host (i.e. the common vole – *Microtus arvalis*), like in the brucellosis and European hare, population density independence was also found (Pikula et al., 2002). The independence of natural foci of brucellosis on the European hare population density can be hypothetically explained by the existence of the so-called home ranges in this species (Kunst et al., 2001). The disease is either present in the environment of the European hare posing a threat of contracting the infectious agent independently of its population density or the territory is brucellosis-free. In the latter case brucellosis can be brought to such a disease-free territory either by transfer of animals when re-populating the hunting grounds or by the migrating second reservoir host – the wild boar (*Sus scrofa*) (Hubalek et al., 2002). When interpreting these interesting results, we also have to consider that the data on the population density of European hare represent 30-year means and thus amount to population levels not encountered in the Czech Republic any more in the present time and that detailed studies using annual data on the European hare and brucellosis distribution would be more appropriate.

Another aspect that should be addressed in future studies into the brucellosis of the European hare is the threshold host population density needed for the continued presence of the pathogen (i.e. persistence of natural foci in a geographic area). Dobson and Meagher (1996) carried out such a study of brucellosis and bison in Yellowstone National Park and demonstrated that brucellosis had a sharply defined threshold for establishment and maintenance in the population of the host. It was found that brucellosis would persist in a bison population of 200 individuals or larger. Our results of independence of brucellosis of the European hare on the population density of the host could therefore be explained by a sufficiently low threshold of the disease in the European hare.

We can speculate that other factors than the population density of the European hare play a role in the maintenance of natural foci of brucellosis (such as climatic factors influencing the survival of the agent in the environment and the chronicity of the disease). *Brucellae* survive for up to 4 months in milk, water and damp soil (Quinn et al., 1994). Our results support the speculation because natural foci of brucellosis occur in such areas of values from the scale of elevation above sea level, annual precipitation, annual temperature and annual sunshine duration in the Czech Republic that might enable *Brucellae* to survive in the external environment. In our opinion, the independence of brucellosis on the European hare density is also reflected by lower numbers of natural foci of brucellosis in specific geographic areas as compared to tularaemia (Pikula et al., 2003).

The study of diseases in relation to the ecosystems in which they are found (landscape epidemiology) is often qualitative, involving evaluations of the ecological factors that affect the occurrence, maintenance and transmission of the infectious agent (Thrusfield, 1995). In this study, however, mainly the quantitative characteristics were used (i.e. population density of the reservoir host, mean annual air temperature, mean annual precipitation, mean annual sunshine duration, elevation above sea level, etc.). We are convinced that quantitative data on the disease occurrence and the use of modern geographic information systems make it possible to make predictions about the disease occurrence and proposal of appropriate control measures. However, further studies into the role of individual factors influencing natural foci of brucellosis will be necessary.

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