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WEATHER CONDITIONS AS A FACTOR FAVOURING THE INCREASE OF TICK – BORNE DISEASES PREVALENCE IN POLAND

WARUNKI POGODOWE JAKO JEDEN Z CZYNNIKÓW ROZWOJU CHORÓB ODKLESZCZOWYCH W POLSCE

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Introduction

Tick-borne diseases are an increasing public health problem in Poland, starting from the early 1950s. Some of the diseases endemic in Poland, like the Central-European tick-borne encephalitis (TBE) and Lyme borreliosis (LB), have been monitored closely by epidemiological surveillance for decades. Some other diseases present on the Poland, like anaplasmosis or babesiosis, are not routinely monitored and their prevalence is not well known. Ticks can also transmit other health-threatening diseases, like tularemia and Q-fever. Among hundreds of bacteria, viruses, and rikettsia found in ticks organisms, an increasing number of microorganisms potentially pathogenic to humans have been detected. The most common tick species in Poland is a competent vector of all the above-mentioned disease pathogens, whereas other ticks play a marginal role in disease transmission (Stańczak et al., 2004). The differences in occurrence of particular diseases are driven by a diverse animal reservoir, specific requirements related to ecosystems and climatic factors. An ongoing European Commission funded EDEN Project attempts studying ecological factors influencing the differences in tick-borne disease prevalence in European countries (Randolph, 2001; Sumilo et al., 2008). Currently available information on tick-borne disease prevalence in Poland is based on systematic studies of prevelence of the TBE virus in ticks, serological surveys of humans, and results of routine epidemiological surveillance.

TBE has the longest history of epidemiological monitoring in Poland. It is caused by a RNA virus belonging to the Flaviviridae family (Monath) and its Central-European type is transmitted by a tick vector – the sheep tick *Ixodes ricinus* (Dumpis et al., 1999). The virus is transmitted between infected ticks developmental stadia, transovarially, and can be transmitted between ticks feeding on the same host. Rodents and, to a lesser extent, larger mammals and birds, constitute the reservoir of the virus. Humans and household animals are incidental hosts. The main sources of infections for humans are bites from infected ticks and consumption of unpasteurized milk from infected household animals. Symptoms of TBE range from asymptomatic course to severe encephalitis, with cranial nerves paresis and loss of consciousness. In most cases the symptoms are mild, nevertheless long-term sequelae are commonly observed.

During previous years, a rise in the incidence of tick-borne diseases was observed in Poland and neighbouring countries. The most common explanations for this are modifications in land cover: reforestation of agricultural areas, supported by the European Union; more common visits by people to the natural environment; and climate changes favourable for tick population growth. Knowing the factors related to the occurrence of tick-borne disease is crucial, since this will allow appropriate targeting of prophylactic interventions. Tick-borne disease prevention is mostly related to personal protection, immunization of the local population and tourists, and education of healthcare workers on the diagnosis and treatment of the diseases.

The main aim of the present study was to describe the geographic distribution of tick-borne diseases in Poland, with a special focus on spatial and temporal variability during the years 1993–2006. The second goal of the study was to indirectly assess the influence of weather and climatic conditions on the tick developmental cycle through analysis of TBE incidence features. It is commonly agreed that the tick activity in particular regions depends on weather conditions, especially air temperature and humidity.

Data and methods

Data collected during the years 1993–2006 were used in the present analysis. Information on the number of TBE cases in districts and communes was obtained from individual case forms reported to the Department of Epidemiology of the National Institute of Public Health. Weather conditions were assessed based on daily meteorological records from 54 synoptic stations, located uniformly in the country. We used mean daily temperatures, minimum temperatures, information on snow cover, and total rainfall. Additionally, we have used data on elevation (DEM – Digital Elevation Model) and land cover and land use.

Standard statistical methods commonly used in biomedical, as well as atmospheric sciences, were utilized, for example correlation, regression, and times series analysis. The main focus of the study was to assess the association of the spatial and temporal distribution of TBE cases with environmental factors, mostly the weather and climatic conditions. For this purpose GIS methods were required, crucial for detailed spatial analyses, with the use of ArcGIS and Surfer software. Spatial analysis of meteorological data was based on the authors' expertise (Ustrnul, Czekierda, 2006), and methods developed within the framework of an EU project COST719 "The Use of Geographic Information Systems in Climatology and Meteorology" (Tveito, Wegehenkel, Van der Wel, Dobesch, 2008). The spatial distribution of TBE case counts was represented using regular kriging, and the distribution of meteorological variables was displayed using the residual kriging method.

Tick-borne encephalitis in Poland in 1993–2006

In order to measure tick density in a particular area and its change over time, dedicated field studies are necessary. Because of the high cost of field work, these studies are performed sporadically and are limited to selected areas. Therefore the number of incident tick-borne disease cases is often considered an indicator of tick activity. Because of the long established surveillance in Poland, we have used TBE as a model disease for the present pilot study. The disease is observed in the entire Polish territory, with a notable maximum in the North-East of the country, including the Mazury Lake District and the Podlasie Lowlands (Fig. 2). During the period studied, 1993–2006, most of the reported cases were from this area, with over 200 cases notified in the Bialostocki and Mikolajski administrative districts. Considerable variation in the number of reported cases was seen during the period studied, the minimum was observed in 1999, and the maximum was seen in 2003 (Fig. 1). Nationally, from 100 to 300 cases were recorded annually, each year the highest number of cases was reported from the North-East of Poland (Fig. 2). We did not find evidence, however, that this region has environmental conditions particularly favourable for tick development and TBE virus amplification. Preliminary studies performed in other areas of Poland indicate that in the Lubelskie and Pomorskie regions a considerable number of TBE infections remain undetected and not reported to the surveillance system. Apart from naturally focused disease distribution, the regional differences are related to diverse epidemiological surveillance performance in different parts of Poland, which influences completeness of reporting. In regions where no TBE cases were historically reported, physicians are not testing patients for TBE. Currently, the Department of Epidemiology is implementing projects aiming at the education of healthcare personnel and improvement of quality of data collected within the Polish surveillance system on TBE and LB. Considering the completeness of the data, we have focused our analysis on Warmińsko-Mazurskie Voivodship.

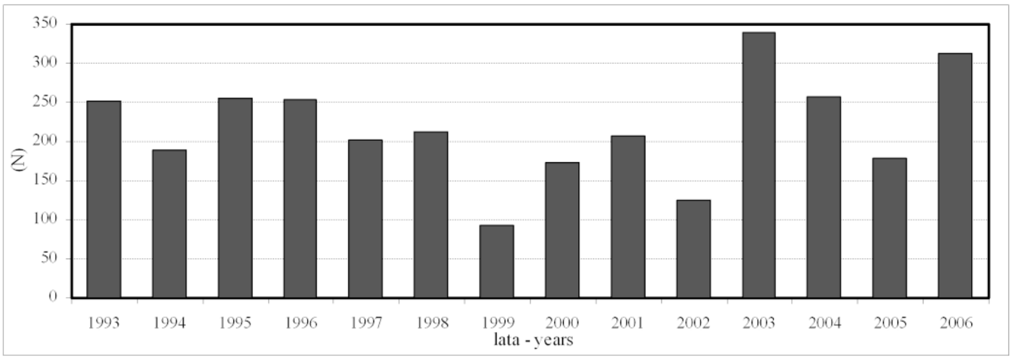

Figure 1. Number of tick-borne encephalitis (TBE) cases by year, Poland, 1993–2006

Influence of meteorological conditions on the number of TBE cases

Based on a literature review, an important role for tick development and TBE virus amplification is attributed to weather and climatic conditions. Although several papers have identified correlation between meteorological conditions and TBE incidence, this association does not have a direct causal relationship. According to experimental models, validated by field studies, rapid autumnal cooling forces hibernation of a large proportion of the larvae that emerged from eggs laid during the summer. If this is accompanied by a fast rise of temperatures during the following spring, a large number of host-seeking larvae, together with nymphs, become active at the same time, which allows amplification of the virus in the organisms of rodent hosts. In favourable conditions, the virus will replicate in amounts sufficient for nymphs and adult tick stages to transmit the infection to humans (Randolph et al., 1999). However, the presence of TBE-infected ticks is not the only prerequisite for the occurrence of human cases. When the environmental field conditions are not favourable, humans will not spend time outdoors and will be not exposed to infected ticks. Because it is not possible to use the results of experimental studies for assessment of risk of TBE infection, an interdisciplinary approach is necessary in which the risk of infection will be estimated based on interrelations between weather, environment, and the tick-density.

The authors of the majority of published studies have found evidence that air temperature has a direct effect on development of all tick stadia. The optimal conditions for tick host-seeking activity is an air temperature above the threshold of 5–7°C. The first step of the present analysis was therefore a detailed exploration of temperature conditions in the studied region during the years 1993–2006.

The studied period was characterized by higher mean temperatures, compared to long term average, with large variations between particular years. The highest mean temperature was identified in 2000, exceeding 9°C in most of the area of Poland, and the lowest mean temperatures were found in 2001, with the average temperature oscillating around 8°C. In years characterized by the minimum and maximum TBE incidence i.e. 1999 and 2003, temperature conditions were relatively comparable. The year 1999 could be classified as warm, whereas 2003 was cooler (Fig. 3). Synthetic climatic analysis should take into account the influence of hygric conditions, best characterised by the total annual rainfall. This measure was characterised by an average value in 1999 (annual total rainfall in most of Poland ranged from 500 to 700 mm), and was much below the long-term average in 2003 (sum of rainfall below 600 mm in most of Poland) (Fig. 3). To conclude, the temperature and rainfall measurements in Poland during 1999 and 2003 cannot be characterised as extremes: thermal conditions were comparable to the long-term average, whereas rainfall in 2003 was below the long-term average, and can be considered as dry.

When evaluating the influence of meteorological conditions on tick development, the climatic factors should be considered based on seasonal, or even daily variability, not relaying solely on annual measures. A detailed analysis of a times series of TBE cases and daily meteorological measurements was performed at national level, and at much more detailed resolution, at district and commune administrative levels. In the first phase, air temperature was computed for each 10 days interval using residual kriging. Figure 4 presents the distribution of air temperatures for the 1st decade of April 2003, when mean daily temperatures rose to above 0°C. In North-Eastern Poland, the mean decadal temperature exceeded 0.5–1.0°C, and in the Western Poland they exceeded 2°C. Anecdotally, the minimum decadal temperature in Poland as a whole remained negative. This indicates clearly that mean air temperature is the most useful measure the influence of thermal conditions on tick development. A similar analysis, using the maximum decadal temperature, did not contribute much to the analysis. The average decadal temperature was used to study the entire study period based on data from selected synoptic North-Eastern stations. Figure 6 presents fluctuations of mean temperatures recorded for the synoptic station in Bialystok in two decades critical for TBE replication in ticks. The temperature trend does not seem to be related to the TBE cases occurrence. In 1999 the 3rd decade of March and 1st decade of April were particularly warm and favourable for tick development. Despite this fact, that year was characterized by the lowest TBE incidence during the study period. In contrast, during the maximum incidence year, 2003, the thermal conditions in 3rd decade of March were close to the long-term average, and the 1st decade of April was the coolest in the entire period studied.

We also analysed the relation between TBE and meteorological conditions using daily measurements and TBE cases time series. Daily air temperature, daily total rainfall and snow cover were included in the analysis. A comparison of TBE temporal variability with the explanatory factors during 2003 (the year with peak disease incidence) is presented in Figure 5. The analysis is limited to weather measurements from the synoptic station in Bialystok and TBE cases reported in Białostocki and Hajnowski administrative districts. The cases are shown with the daily resolution moved 4 weeks backwards, which reflects the typical period from exposure to tick bite to the symptom onset. The graph does not show conclusive associations, similarly as analysis for the remaining years analysed. Only a weak association between air temperature and TBE case occurrence can be seen in the selected time periods, although the analysis may be limited by the low number of cases. The final step of the present analysis was to assess the correlation between TBE cases and meteorological measures aggregated to decades. Table presents the results of this analysis for the years 1999–2006,

Table. Correlation coefficients between different meteorological variables and the number of cases of the tick-borne diseases (TBE) – based on the Białystok weather conditions and Białystok Voivodship TBE series

	TMX	TMN	TSR	TMN_5	P	SC	KZM/TBE
TMX	1,00						
TMN	0,95	1,00					
TSR	0,99	0,98	1,00				
TMN_5	0,91	0,99	0,95	1,00			
P	0,22	0,32	0,26	0,35	1,00		
SC	–0,53	–0,58	–0,56	–0,59	–0,12	1,00	
KZM/TBE	0,58	0,58	0,58	0,57	0,20	–0,27	1,00

Explanations: coefficients calculated on the decadal values from the period 1999–2006; TMX – maximum temperature, TMN – minimum temperature, TSR – mean temperature, TMN5 –minimum ground temperature, P – precipitation total, SC – snow cover depth, KZM/TBE – number of cases of the tick-borne diseases based on measurements from the synoptic station in Białystok and TBE cases reported in the Białystok and Hajnówka administrative districts. The relationship between all temperature measures and TBE case counts are apparent and statistically significant at the level of p=0.05. Correlations with other meteorological factors (rainfall, snow cover) are much weaker, although the correlation coefficient between the number of TBE cases and the number of days with rainfall remains statistically significant. This analysis indicates that weather conditions do influence TBE occurrence. A better understanding of the studied relationships requires more complete data and more in-depth studies of the influence of meteorological conditions on the development of ticks and amplification of the TBE virus.

Conclusions

In the paper we have presented the spatial distribution of TBE cases, which is one of the most severe tick-borne diseases in Poland. The disease may indirectly reflect the tick activity in space and time. According to the present analysis, the highest disease incidence is observed in Mazury Lake Region and Podlasie Lowlands. These regions were affected by the highest disease incidence during the entire study period 1993–2006 and in the minimum incidence year (1999) and highest incidence year (2003). Incoherent data on disease incidence from the entire country do not allow interpretation at such high spatial diversity. Two spatial analysis methods were used: regular kriging and residual kriging, which have been shown as detailed and very useful tools for this kind of analysis.

Detailed analyses of the relation between TBE cases and meteorological conditions in North-Eastern Poland have confirmed the association between those variables. In particular, a statistical association between decadal air temperature and the aggregated number of cases was identified. Based on actual data, it is difficult to document a direct association between daily meteorological measures and the TBE cases time series. Analysis of larger samples of data, especially of tick-borne disease cases or infections, may permit obtaining of more conclusive results.

Planned multivariate analysis may help elucidate the association between TBE incidence and environmental conditions. It will include, in addition to meteorological conditions, detailed data on vegetation, socio-economic status of the local population, tourist traffic and other factors which can influence tick activity, their reservoir hosts and human behaviour. This approach will necessitate even more extensive use of GIS techniques with the use of multiple thematic layers.

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References

Dumpis U., Crook D., Oksi J., 1999: Tick-borne encephalitis, *Clin Infect Dis*, 28(4), 882-890.

Randolph S.E., 2001: The shifting landscape of tick-borne zoonoses: tick-borne encephalitis and Lyme borreliosis in Europe, *Philos Trans R Soc Lond B Biol Sci*., 356, 1045-1056.

Randolph S.E., Miklisova D., Lysy J., Rogers D.J., Labuda M., 1999: Incidence from coincidence: patterns of tick infestation on rodents facilitate transmission of tick-borne encephalitis virus. *Parasitology*, 118, 177-186.

Stańczak J., Gabre R.M., Kruminis-Lozowska W., Racewicz M., Kubica-Biernat B., 2004: Ixodes ricinus as a vector of Borrelia burgdorferi sensu lato, Anaplasma phagocytophilum and Babesia microti in urban and suburban forests, *Ann Agric Environ Med.*, 11, 109-114.

Sumilo D., Asokliene L., Bormane A., Vasilenko V., Golovljova I., Randolph S.E., 2007: Climate change cannot explain the upsurge of tick-borne encephalitis in the Baltics, PLoS ONE 2(6): e500. doi:10.1371/journal.pone.0000500.

The Use of Geographic Information Systems in Climatology and Meteorology, 2008: (eds.) Tveito O.E., Wegehenkel M., Van der Wel F., Dobesch H., EUR 23461, COST Action 719 – Earth System Science and Environmental Management, Brussels.

Ustrnul Z., Czekierda D., 2006: Metody analizy przestrzenno-czasowej w badaniach klimatologicznych (na przykładzie Polski), *Roczniki Geomatyki,* t. 4, z. 2, 147-156.

Abstract

Tick-borne diseases are a severe public heath problem in Poland, which is increasingly recognized in recent years. The present analysis focuses on tick-borne encephalitis (TBE), for which data are available from Poland for a relatively long period, and is a potentially life-threatening problem. The spatial distribution of TBE cases is described, and temporal variability during the period 1993–2006 is assessed. Most of TBE cases are reported from the North-Eastern part of Poland, although the quality of surveillance data collected in different parts of the country is not uniform. The highest number of cases was reported in 1999, and the lowest in 2003. The association of meteorological factors on TBE incidence is assessed, including air temperature parameters, precipitation, and snow cover. Analyses were attempted using seasonal, decadal, and daily meteorological measurements. Preliminary results have confirmed a statistically significant relationship between air temperature and occurrence of TBE cases. The relationship with other factors is quite probable, but confirmation requires more comprehensive data on tick-borne diseases and multivariate analysis will be necessary. The final multivariate model should include not only meteorological conditions, but also information on the environment and human behaviour.

Streszczenie

W pracy przedstawiono zagadnienie chorób odkleszczowych, które stanowią poważny problem w Polsce, zwłaszcza w ostatnich latach. Szczególną uwagę poświęcono kleszczowemu zapaleniu mózgu (KZM), które na obszarze Polski jest stosunkowo długo monitorowane i jednocześnie bardzo niebezpieczne dla człowieka. Omówiono zróżnicowanie przestrzenne zachorowań na KZM z uwzględnieniem powiatów i gmin, a także zwrócono uwagę na zmienność w rozpatrywanym wieloleciu 1993-2006. Dane jednoznacznie wskazały, że największa liczba zachorowań notowana jest w północno-wschodniej Polsce, choć autorzy zwracają uwagę na wątpliwości co do jednorodności uzyskanych danych. W wieloleciu zanotowano znaczne różnice w liczbie zachorowań. Najmniej wystąpiło ich w 1999 roku, najwięcej w 2003. W pracy zwrócono uwagę na wpływ warunków meteorologicznych na liczbę zachorowań na KZM. Uwzględniono kilka elementów meteorologicznych, w tym: temperaturę powietrza z różnymi jej charakterystykami, opad atmosferyczny, pokrywę śnieżną. Wykonano analizy oparte na danych sezonowych, dekadowych oraz dobowych. Wstępne wyniki potwierdziły istotnie statystyczny związek pomiędzy temperaturą po-

wietrza a zachorowaniami. Wpływ innych elementów jest prawdopodobny, ale wymaga on szczegółowych badań na bogatszym materiale badawczym i przy zastosowaniu analizy wieloczynnikowej. Powinna ona obejmować nie tylko warunki meteorologiczne ale również inne dane o środowisku i człowieku.

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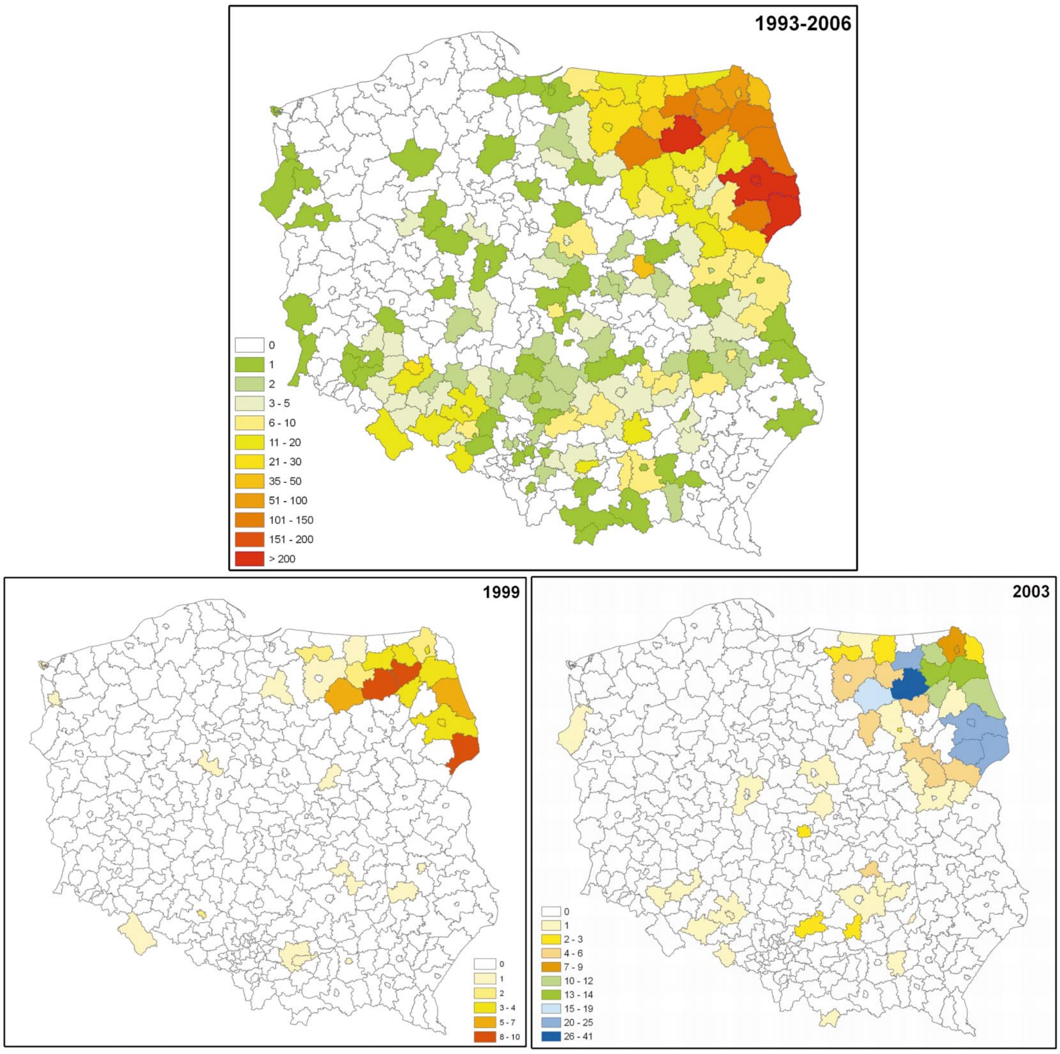

Figure 2. Number of tick-borne encephalitis (TBE) cases in counties

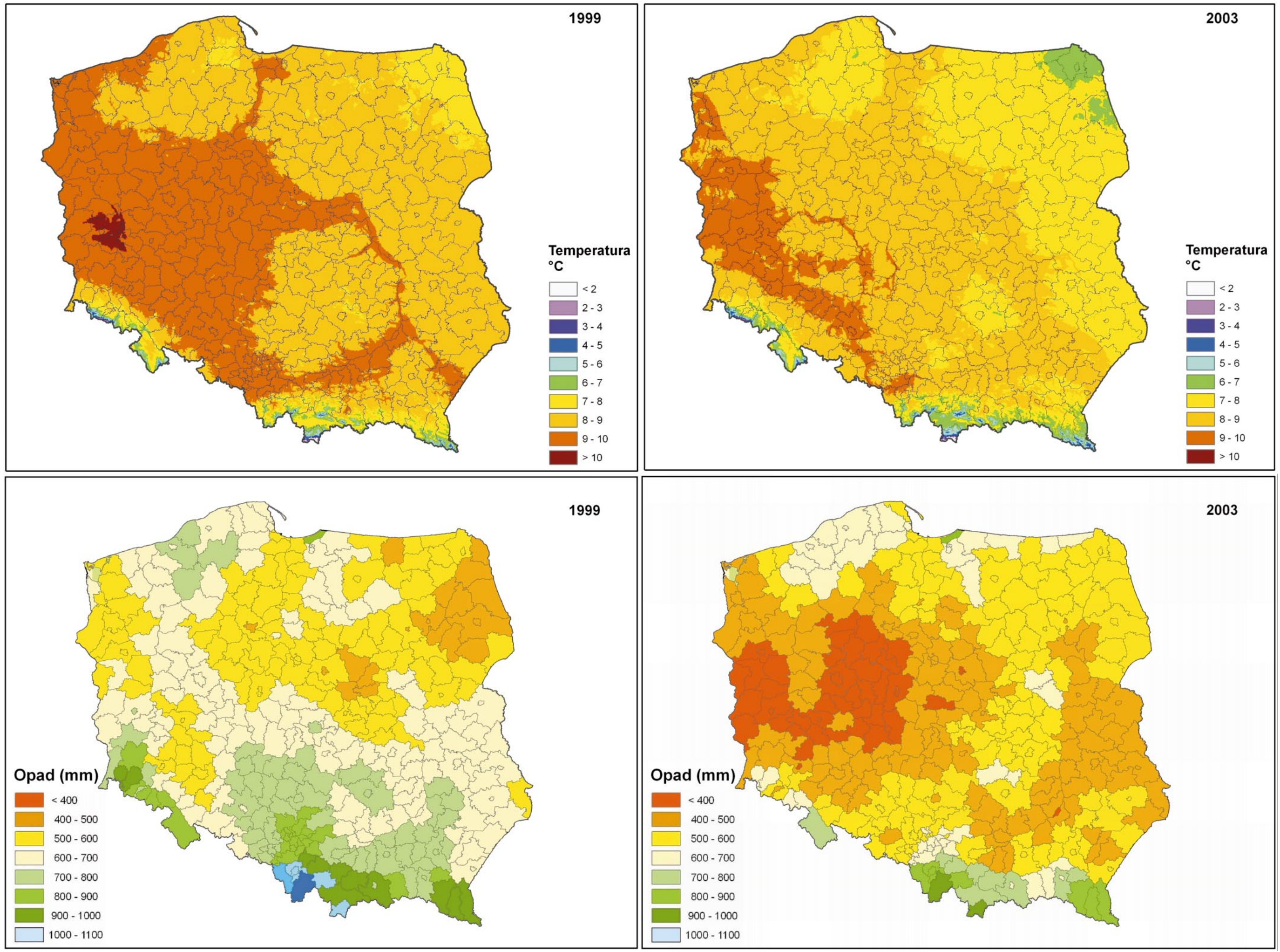

Figure 3. Mean annual air temperature and mean annual precipitation totals in Poland in 1999 and 2003

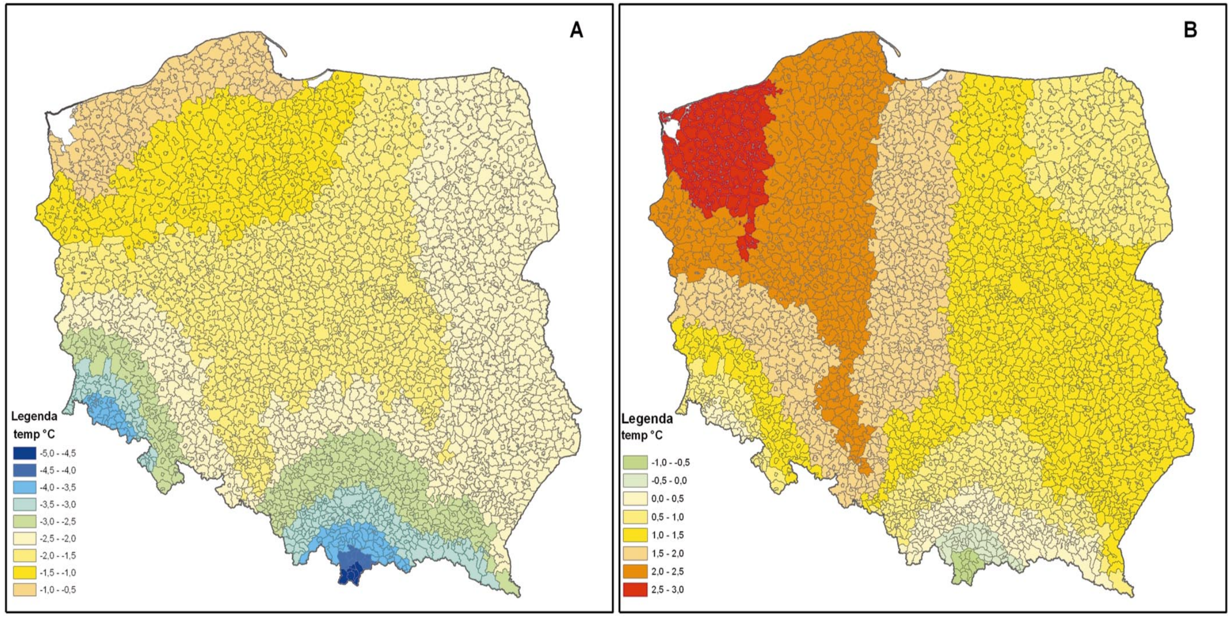

Figure 4. Distribution of the mean decadal air temperature (1-10 April 2003) in the particular communes in Poland: A – minimum values, B – mean values

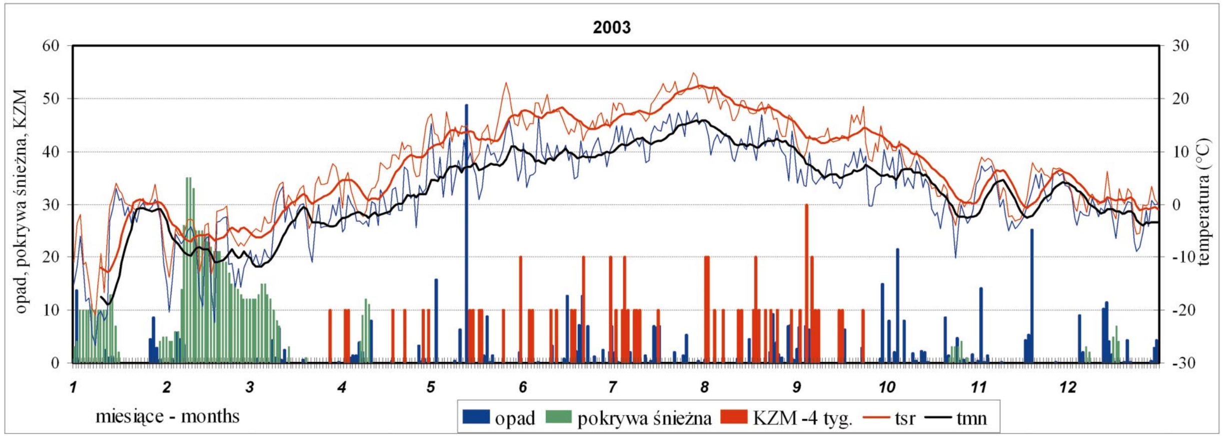

Figure 5. The course of the selected meteorological elements at the Białystok stationin 2003 (Explanations: data of KZM (TBE) originate from the Białystok and Hajnówka county, values multiplied by 10 are opad – precipitation, pokrywa śnieżna – snow cover, tsr – mean daily temperature, tmn – minimum daily temperature; temperature values are also smoothed by the 10 years moving averages)

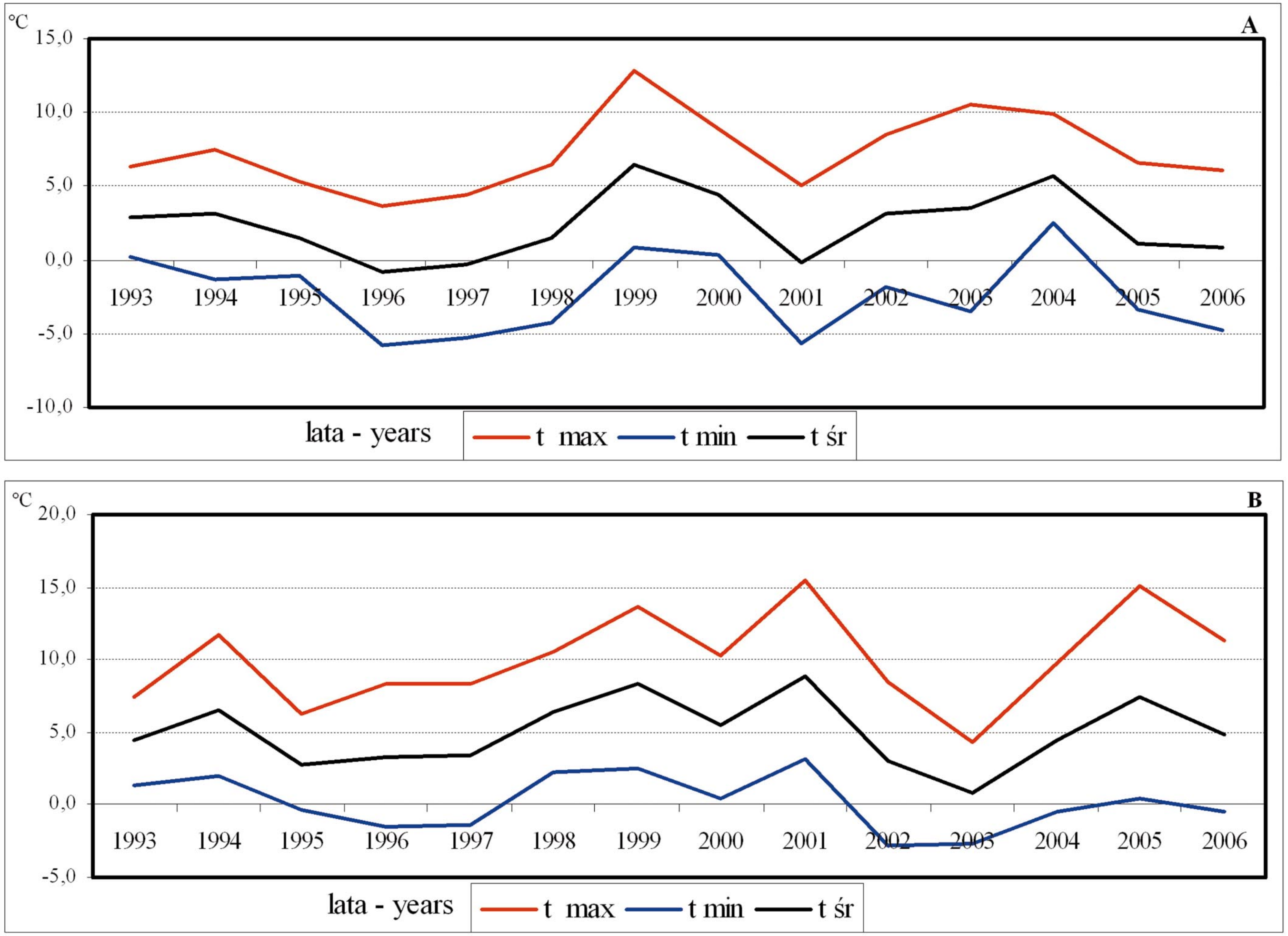

Figure 6. The course of the mean decadal air temperature at the Białystok station in the period 1993–2006: A – temperature of the third decade of March, B – temperature of the first decade of April