Temporal changes in rodent and tick-borne diseases in Europe: how are they linked?

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Background. Generalist rodent species, such as the yellow-necked mouse (*Apodemus flavicollis*) and the bank vole (*Myodes glareolus*), play an important role as reservoirs of a number of directly transmitted zoonotic pathogens, such as hantaviruses, as well as tick transmitted pathogens, such as tick borne encephalitis virus and *Borrelia* spp. Since the incidence of rodent and tick borne diseases varies spatially and temporally in European citizens, understanding the drivers of such variation is relevant for identifying early warning predictors of change in disease risk. In particular, understanding the consequences of rodent fluctuations on the pathogens dynamics can provide a framework for the prevention of the above pathogen set. In fact, the wood tick (*Ixodes ricinus*) can acquire the infections while feeding on rodents which represent about the 30% of the tick blood meals (see Collini et al.; **poster n. 2.18**) but several other species need to be considered**.** Therefore, given the complexity of this system, the impact of temporal variation in rodent density on the tick borne pathogens 'infection hazard' (measured as questing tick infection rate) can be modelled only for those pathogens where rodents play a significant contribution in terms of reservoir capacity.

Methods. We established a joint multiannual monitoring survey in three European countries (Italy, Slovakia and Finland). Collection of questing ticks and rodents were carried out in our study sites for three consecutive years. Serological and molecular investigations were carried out both on rodents and ticks collected either from vegetation and directly from the hosts to identify their infectious status and prevalence of infection. Ticks pathogen screening was completed so far for the study sites in Italy (Cavedine) and Slovakia (Rovhanovce) (see Baráková et al. **poster 3.18** and Kazimírová et al **poster n. 4.5 for** details on methods and results for each pathogen). Statistical analysis were carried out by the use of Generalized Linear Models and Chi squared statistical tests.

Results

In Italy, we observed a positive correlation between the number of co-feeding ticks on hosts recorded at year (*t*-1) and TBE seroprevalence in *Apodemus flavicollis* detected the following year (*t*) (Fig. 1B) (GLM output: estimate for no. of co-feeding = 0.04, z-value=2.96, p<0.01). In addition, an hump-shaped relationship between rodent density and co-feeding ticks in the same year of sampling was observed (Fig. 1C) (GLM output: estimate for rodent density=0.19, z-value=2.26, p<0.05; estimate for (rodent density)^2=-0.011, z-value=-2.57, p<0.01). Thus, intermediate values of rodent density maximize the number of co-feedings on rodents and consequently TBE infection the following year.

For bacterial tick-borne pathogens (*Borrelia* spp., *Borrelia afzelii* and *Candidatus N. mikurensis*), differences in pathogen prevalence, detected in questing ticks among different years of sampling (2011-2013) were observed only for *Borrelia afzelii* in Rozhanocve site in Slovakia (Fig. 2C) (Chi-squared=12.46, df=2, P<0.01), where infection prevalence in questing nymphs was higher in 2011 in respect to 2012 and 2013 while no difference were observed between 2012 and 2013. For all the other sites and pathogens no difference were observed among years (Figs. 1D and 2D)

Figure 1. (A) Annual variation of *Apodemus flavicollis* density observed at the Italian site of Cavedine during the period 2000-2013. (B) Total no. of co-feeding observed in previous year (*t*-1) on TBE negative/positive rodents at year (t). (C) Effect of rodent density on annual total co-feeding observed on rodents. (D) Annual variation of *Borrelia afzelii* prevalence detected in questing nymphs at the Italian site of Cavedine during the period 2011-2013.

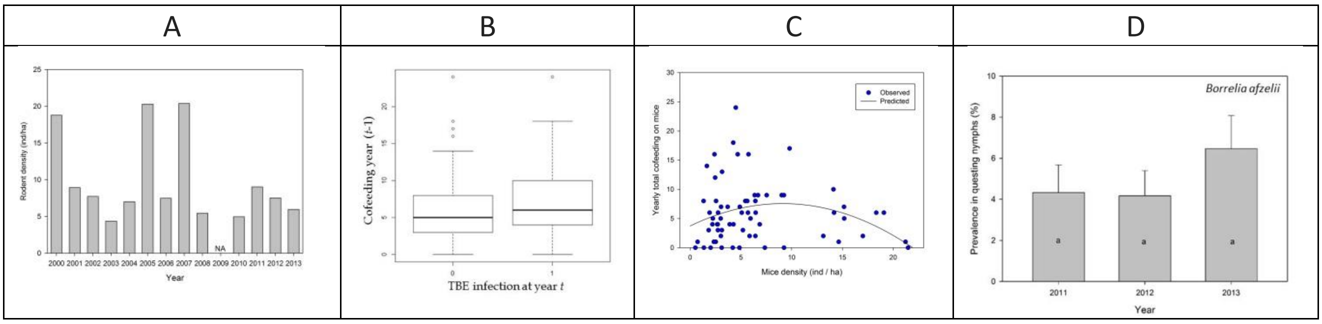
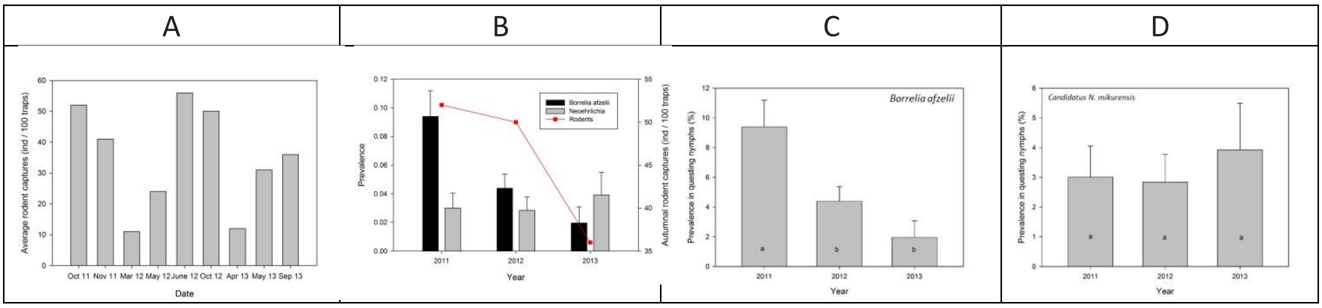


Figure 2. (A) Seasonal variation of rodent abundance observed at the Slovakian site of Rovhanovce during the period 2011-2013. (B-D) Annual variation of *Borrelia afzelii* and *Candidatus N. mikurensis* detected in questing nymphs at the Slovakian site of Rovhanovce during the period 2011-2013.



Discussion

In general, rodent-borne and tick-borne diseases cannot be easily controlled with the in discriminant use of rodenticide, acaricide or large-scale animal culling. Instead, preventing and reducing the exposure of humans to such pathogens and their vectors within identified hot spots of infection during periods when the infection hazards is highest, is a more realistic and sustainable option. However, these recommendations are only possible if such hazards are predictable. Within our joint ROBO-TBD program, we obtained significant results for the TBEV- *I. ricinus* - *A. flavicollis* system, while for other tick transmitted pathogens the relationships were not significant in the majority of the cases. This might be due to the reduced variation in the observed rodent abundance over the three study years, where high population peaks were not observed comparing to the previous ones, but further analysis are currently in progress to explore the effect of other variables, as variation in the climatic parameters.

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