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Original Research

Modeling sheep pox disease from the 1994–1998 epidemic in Evros Prefecture, Greece

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ABSTRACT

Sheep pox is a highly transmissible disease which can cause serious loss of livestock and can therefore have major economic impact. We present data from sheep pox epidemics which occurred between 1994 and 1998. The data include weekly records of infected farms as well as a number of covariates. We implement Bayesian stochastic regression models which, in addition to various explanatory variables like seasonal and environmental/meteorological factors, also contain serial correlation structure based on variants of the Ornstein–Uhlenbeck process. We take a predictive view in model selection by utilizing deviance-based measures. The results indicate that seasonality and the number of infected farms are important predictors for sheep pox incidence.

1. Introduction

Sheep pox is a highly contagious viral infection of sheep (Garner et al., 2000). The causative agent belongs to the genus Capripoxvirus, one of the six genera of poxviruses of vertebrates (Yeruham et al., 2007). The causative virus of sheep pox is antigenically and genetically closely related to goat pox virus and lumpy skin disease virus. The disease spreads by the direct contact with infectious animals and indirect contact with contaminated objects; for example, the virus could survive for many years in dried scabs at ambient temperatures and for 2 months on wool (OIE, 2002). Infected sheep may transmit the virus (or the causative agent) at every stage of the disease, even up to eight weeks after the lesions have resolved (Singh et al., 1979). An additional transmission route is through biting flies (Kitching and Mellor, 1986). The transmission of sheep pox between flocks occurs when sheep are moved from flock to flock. This type of movement occurs frequently in the Middle East (DEFRA, 2012) (For a comprehensive review on the history and distribution of the disease worldwide see Rao and Bandyopadhyay (2000) and Bhanuprakash et al. (2006)).

The disease may spread rapidly, resulting in the fatality of infected animals within a few days. This form of the disease is seen mostly in lambs. Characteristic symptoms are fever and paralysis. An eruption in the form of red spots appears on the membranes of the eyes and nose, and on the wool-free parts of the skin. In older sheep, the disease begins by signs of serious ill-health, notably a high temperature and suppressed appetite (DEFRA, 2012). Infected pregnant ewes often abort. The disease is characterized by high mortality rates and significant decreases in milk production (Yeruham et al., 2007; Belwal et al., 1982). Economic losses due to mortality and milk production losses are also noticeable (Senthilkumar et al., 2010; Garner et al., 2000).

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Another characteristic of the disease noted in the relevant literature is the one of seasonal variations of outbreaks of sheep pox. Specifically, most studies associate sheep pox occurrence with unusual winter conditions and report that the majority of outbreaks occur during the winter and spring months (e.g. Hailat et al., 1994; Yeruham et al., 2007; Bhanuprakash et al., 2005). There are also various environmental/meteorological factors which can influence disease occurrence, such as the amount of rainfall, relative humidity and maximum temperature (e.g. Bhanuprakash et al., 2004, 2005; Webster, 1981).

Sheep pox is widely distributed in Asia and North and East Africa. Most of Europe and the Americas are now free from endemic sheep pox. However, the disease has occurred in Greece in 2000 (only 1 infected herd). Greece has a history on sheep pox appearances in the recent years. Specifically, in 1987 there was an incidence of sheep pox in the island of Lesbos which consisted of four outbreaks. The disease was controlled via culling of infected animals and vaccination of the neighboring farms within the protected zone (Mangana et al., 2008). Re-appearance of the disease occurred with a single outbreak in the Evros Prefecture during 1988. This last case of sheep pox in the Evros Prefecture, before the major outbreak of 1994, was controlled through the slaughtering of infected flocks and vaccination of all sheep farms near the Evros river. 1992 was a turning point regarding the implementation of control policies aimed at eradicating sheep pox outbreaks in Greece. In particular, a stamping out/non-vaccination policy replaced policies which up to then included, in addition to slaughter of infected animals, vaccination of the neighboring farms for controlling the disease. The new control measures also included the cleaning and disinfection of culled premises and the establishment of protection and surveillance zones of a radius of 3 and 10 km, respectively, around the outbreak.

A major outbreak appeared in Evros in 1994, and over the next four years several outbreaks occurred in Evros and Thessaloniki (1995), Larissa, Xanthi, Rhodopi, Kavala, Magnissia, Evros and Lesbos in 1996, Kavala, Magnissia, Halkidiki, Evros and Rhodopi in 1997. A decline of sheep pox outbreaks was eventually achieved in 1998, with outbreaks restricted only in the Evros Prefecture. Following an absence of appearance in 1999, sheep pox has re-appeared in 2000 (only a single incidence).

During 1996 we observed the highest frequency of sheep pox incidents in Greece. This high rate of appearance of sheep pox is attributed to various factors, such as efficient reporting of outbreaks at that time, a higher number of susceptible animals and host/agent factors (Mangana et al., 2008).

Evros Prefecture is a critical area as regards the appearance of contagious animal diseases on European soil (another example is foot-and-mouth disease (FMD)). This is due to that it constitutes the natural passage for the transfer from Asia to Europe of infectious diseases endemic in their regions of origin (EFSA, 2006). Sheep pox caused serious economical losses to the livestock of Evros Prefecture. During the last major sheep pox epidemic in 1998, eradication measures have been implemented to control the disease. Stamping out of the animals from affected flocks and flock vaccination for the risk areas have been implemented. As Mangana et al. (2008) stress, the geography of the region, with river Evros constituting the natural border between Greece and Turkey and Bulgaria, makes it easy for sheep in the Greek soil to come in close contact with scabs from dead animals that could transmit the disease. Another possible reason could be attributed to the movement of workers and farmers from neighboring countries (i.e. Turkey and Bulgaria), where sheep pox outbreaks are frequent. Dadousis (2003) also relates sheep pox outbreak in Greece with Turkey based on the evidence of high incidence rate in Turkey and the 1996–1997 epidemic peak in Evros, Greece. There is additional evidence to believe that pox virus was introduced in Greece from Turkey, since the disease is endemic in Turkey and the primary incidents have been detected close to Evros river which mostly determines the border with Turkey (Dadousis, 2003).The aim of the current study was to examine the dynamics of the spread of sheep pox and to address the various epizootiology issues described previously (e.g. temporal and climatic factors) in this sensitive region. In doing so, we implement Bayesian stochastic regression models to describe sheep pox occurrences in Evros during 1994–1998. A stochastic regression model differs from a standard regression model in that the former allows for one or more of the explanatory variables, such as U_i, to be random. A number of explanatory variables were utilized, including seasonal and environmental/meteorological factors, in order to assess the magnitude of their effect on the occurrence of the outbreak. In addition, serial correlation structure, based on variants of the Ornstein–Uhlenbeck process represents an integral part of our modeling approach.

2. Materials and methods

2.1. Data

The sheep pox epidemics of the Evros Prefecture of Northeastern Greece began on November 1994, ended in December 1998 and included 249 infected premises (a re-appearance of the disease with only one infected herd occurred in 2000). The course of the epidemic from 1994 up to 2000 is depicted in the following map (Fig. 1).

Farm-level data for the sheep pox epidemic were obtained from the Veterinary Directorate of Northern Evros Prefecture *(VDNEP)*, located in the city of Orestiada, Evros Prefecture, Greece. Treating each infected farm as a single unit, the data comprised of daily records on the number of infected farms. Temporal information, important for identifying the progress of disease through time was also made available, such as the exact day of the putative infection time (as determined by the examination of the infected animals in each farm by the local veterinary services). The daily records were transformed to weekly records to avoid substantial uncertainties related to the exact day of infection. Spatial information concerning the location of each farm was not available. However, we obtained a crude approximation of the farm location by