Risk analysis on the introduction into free territories of vaccinated animals from restricted zones

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Summary

Between August 2000 and 14 May 2001 (defined as the 2000-2001 epidemic) bluetongue (BT) was reported in three regions of Italy: Sardinia, Sicily and Calabria. During the 2001-2002 epidemic (between 15 May and 14 April 2002), the disease spread to five additional regions (Puglia, Basilicata, Campania, Latium and Tuscany). In May 2001 the Italian Ministry of Health decided to restrict animal movements and to vaccinate all susceptible domestic ruminant populations in infected and in neighbouring regions. This action was taken to reduce virus circulation with the aim of decreasing direct losses in sheep and goats due to the disease, and indirect losses in cattle populations due to movement restrictions. Furthermore, the Italian authorities implemented an epidemiological surveillance system to monitor the spread of the virus and to provide more effective movement controls. In 2002, the vaccination campaign reached the set goal of vaccinating more than 80% of susceptible domestic ruminants in Abruzzo, Sardinia and Tuscany. The vaccination campaign successfully reduced clinical disease in Sardinia and Tuscany. Before the advent of BT, cattle had always been moved from Sardinia, Sicily and the southern regions for fattening and slaughter in northern Italy. During the tracing of animals that had left infected areas in 2000 it was found that 10 957 cattle had been exported from Sardinia between June and August 2000 and were scattered throughout continental Italy. In addition, most cows selected for culling from the southern regions and the islands were sent to northern Italy for slaughter. However, since August 2000 the animal trade between infected and free areas has come to a complete standstill. Sardinia, in particular, due to the climatic and epidemiological conditions (vectors survive almost throughout the year), was no longer able to export any ruminants to the mainland. Long-term standstill therefore led to heavy economic losses and had even greater social consequences. As farmers are not compensated, it is impossible to enforce these restrictions indefinitely. The Italian authorities and the European Commission thus decided to adopt a policy of risk management allowing some animal movement. This paper presents an analysis that assesses the risk associated with animal movement from restricted areas, according to the level of immunity of susceptible animal populations due to vaccination in the same areas. Results of the analysis indicate that when more than 80% of the susceptible population in the territory of origin is vaccinated, the risk associated with the movement of vaccinated animals to free areas appears acceptable and can be mitigated further by adopting ancillary control measures.

Keywords

Animal movement – Bluetongue – Control strategy – Italy – Risk analysis – Trade –Vaccination.

Introduction

From August 2000 to 14 May 2001 bluetongue (BT) was reported in three regions of Italy: Sardinia, Sicily and Calabria (1). During the second BT epidemic (from 15 May to 14 April 2002) the disease spread to five additional regions (Puglia, Basilicata, Campania, Latium and Tuscany) (3). The high economic losses due to movement restrictions in infected areas and the need to reduce virus circulation as far as possible persuaded the Ministry of Health to vaccinate susceptible domestic ruminants; vaccination involved sheep, goats and cattle. This was done to create a resistant population to either reduce or interrupt BT virus (BTV) circulation, at least in those zones with low levels of virus and vector pressure. The selection of the vaccination strategy was based on a risk assessment which indicated that the viral circulation throughout Italy could be significantly reduced by obtaining a large population of ruminants resistant to infection (2).

The vaccination campaign commenced in Sicily in October 2001, in Sardinia and in Calabria in January 2002, and in Latium and Tuscany in March 2002. In 2002, the goal of vaccinating more than 80% of susceptible domestic ruminant populations, set by the Ministry of Health (4), was achieved only in Abruzzo, Sardinia and Tuscany. The vaccination campaign successfully reduced clinical disease. In Sardinia, the number of clinical outbreaks declined from 6 090 in the 2001-2002 epidemic to 10 outbreaks in 2002-2003. In Tuscany, after 158 outbreaks in the 2001-2002 epidemic, the clinical disease disappeared altogether.

Since August 2000, animal trade between infected and free areas has come to a complete standstill. Due to the climatic and epidemiological conditions specific to Sardinia, vectors survive throughout the year. For this reason, all movements of ruminants to the mainland was prohibited. Long-term standstill leads to economic losses and negative social consequences which are sometimes greater than those due to the disease. As farmers did not receive compensation, the standstill measures could not be enforced indefinitely. The aim of this paper is to assess the risk associated with animal movement from restricted areas, according to the level of immunity induced by vaccination of susceptible animal populations in the same areas.

Materials and methods

Risk assessment on introduction of viraemic animals into free areas through animal trade

A simulation model was developed to assess the expected number of viraemic animals introduced into free areas from infected areas. The following assumptions were considered in the risk assessment:

a) besides vaccination, no other epidemiologically relevant factor (e.g. abundance of vectors, vector activity and climatic variables) differed significantly compared to previous years
b) the incidence of infection was estimated assuming a decrease in a vaccinated population compared to a non-vaccinated population proportional to the product of infected multiplied by susceptible animals
c) duration of viraemia that could result in the transmission of infection, 60 days (conservative assumption)
d) random selection of animals to be moved to uninfected areas.

The following input variables were used in the model (the source of the data is given in brackets):

a) population of susceptible species (local Veterinary Services)
b) number of vaccinated animals, by species (local Veterinary Services)
c) average monthly incidence of infected cattle in previous years (archives of the national BT information system)
d) average monthly incidence of infected sheep during previous years (archives of the national BT information system)
e) frequency distribution of serum neutralising (SN) antibody titres (archives of the national BT information system).

The output variables of the model were:

a) number of new cases in the vaccinated population each month (simulated on the basis of the binomial distribution, the total number of susceptible animals and the incidence of infection in the vaccinated population)
b) incidence of infection in free areas that surround infected areas which was calculated on the basis of:
   i) the mean delay from the onset of a new case of infection and the adoption of restrictions
   ii) the population within a radius of 20 km from the new case
   iii) number of new cases in the vaccinated population monthly

   the choice of a 20-km radius is based on the definition of infected area around any new evidence of BTV circulation, stated by the law (5)
c) prevalence of viraemic animals in the vaccinated population (calculated on the basis of the number of new cases per month and the assumed duration of viraemia)
d) number of viraemic animals moved to a free area (simulated on the basis of the prevalence of viraemic animals and of eight different scenarios according to animal species, number of animals moved and presence/absence of virus circulation in the territories of origin.

The model was implemented using @Risk© software (Palisade Corporation) (7). The expected number of viraemic animals moved to a free area was simulated through 10 000 iterations, with Latin hypercube sampling. Three scenarios were considered, describing different types of territory that were chosen as paradigmatic examples, as follows:

a) scenario A, a territory in which >80% of the total animal population has been vaccinated and the incidence of infection in previous years was high

b) scenario B, a territory in which about 50% of the total animal population has been vaccinated
c) scenario C, a territory in which a negligible fraction of the total population has been vaccinated.

Validation of the model

The model was validated using data from Sardinia and Tuscany, derived from the national BT surveillance system. In particular, the expected prevalence of viraemic animals in Sardinia and Tuscany, simulated by the model, was compared with the number of sentinel animals that seroconverted in a period extending 100 days. In relation to the value of minimal protective antibody titres, two different scenarios were considered in the model validation, as follows:

1) all vaccinated animals are protected against the infection, irrespective of antibody titre
2) only animals with an SN antibody titre of at least 1:10 are protected against infection.

Results

Validation of the model

Results of the two scenarios were compared with surveillance data. Figure 1 presents the probability distributions of the number of positive sentinels in Tuscany and Sardinia, respectively. The number of positive sentinels observed during the previous 100 days in Tuscany was 6, which is compatible with both scenarios under consideration, while in Sardinia the number of positive sentinels observed was 28, which is compatible with immune protection of animals, irrespective of circulating antibody. The number of positive sentinels foreseen by the model varied from 26 to 34, with a median value of 30. Consequently, the model was considered capable of predicting the expected monthly number of new cases. In subsequent simulations, therefore, all vaccinated animals were considered protected against infection.

Risk assessment on introduction of viraemic animals in free areas through animal trade

The results of the risk assessment varied according to the different scenarios considered, as follows:

a) if 5 000 cattle are selected at random from a population of domestic ruminants in which vaccinated animals represent less than 80% of the total (scenarios B or C), irrespective of the fact that they are selected in either infected or uninfected areas, the expected number of viraemic animals among them varies between 384 and 938 (Figs 2 and 3); if 5 000 sheep are chosen at random from the same areas, the expected number of viraemic animals among them varies between 64 and 429 (Figs 2 and 3)

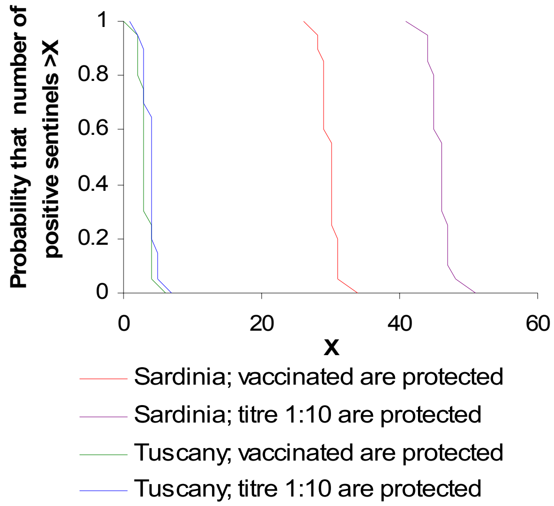

Figure 1
Expected numbers of positive sentinels in Tuscany and Sardinia according to the hypotheses that either all animals vaccinated against bluetongue are protected against infection or that only animals with an antibody titre of at least 1:10 are protected against infection

b) if 5 000 cattle are chosen at random from a population of domestic ruminants in which vaccinated animals represent more than 80% of the total (scenario A), irrespective of the fact that they are selected in either infected or uninfected areas, the expected number of viraemic animals among them varies between 10 and 56 (Fig. 4); if 5 000 sheep are selected at random from the same areas, the expected number of viraemic animals among them varies between 0 and 12 (Fig. 4)
c) if 5 000 cattle are selected at random from a population of domestic ruminants in which vaccinated animals represent less than 80% of the total (scenarios B or C) and originate in uninfected areas, the expected number of viraemic animals sent to free areas varies between 28 and 141 (Figs 5 and 6); if 5 000 sheep are chosen at random from the same areas, the expected number of viraemic animals among them varies between 0 and 69 (Figs 5 and 6)
d) if 5 000 cattle are chosen at random from a population of domestic ruminants in which vaccinated animals represent more than 80% of the total (scenario A) and originate in uninfected areas, the expected number of viraemic animals sent to free areas varies between 0 and 9 (Fig. 7); if 5 000 sheep are selected at random from the same territories, the expected number of viraemic animals among them varies between 0 and 3 (Fig. 7).

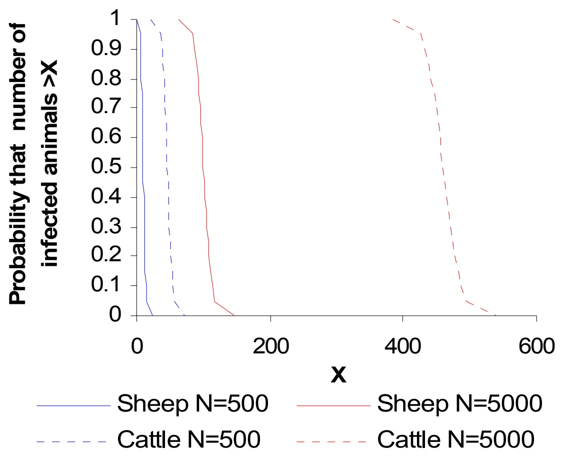

Figure 2
Expected number of viraemic cattle and sheep moved to areas free of bluetongue in the case of random selection of animals from the entire regional population (irrespective of infected or uninfected areas): Scenario B

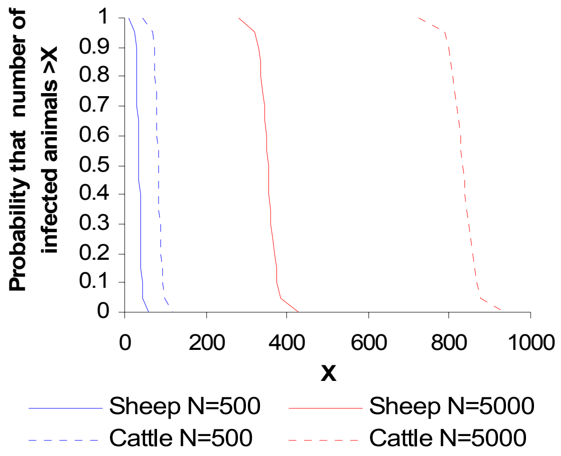

Figure 3
Expected number of viraemic cattle and sheep moved to areas free of bluetongue in the case of random selection of animals from the entire regional population (irrespective of infected or uninfected areas): Scenario C

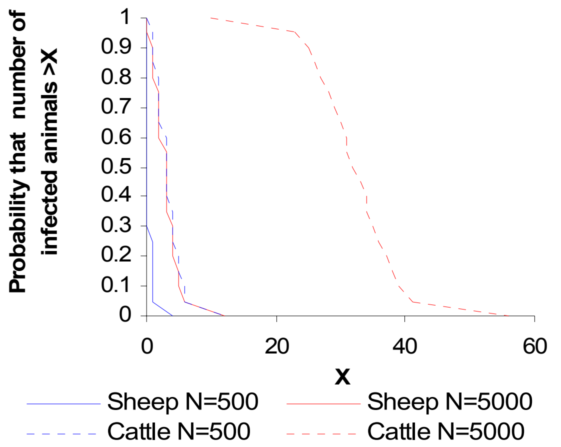

Figure 4
Expected number of viraemic cattle and sheep moved to areas free of bluetongue in the case of random selection of animals from the entire regional population (irrespective of infected or uninfected areas): Scenario A

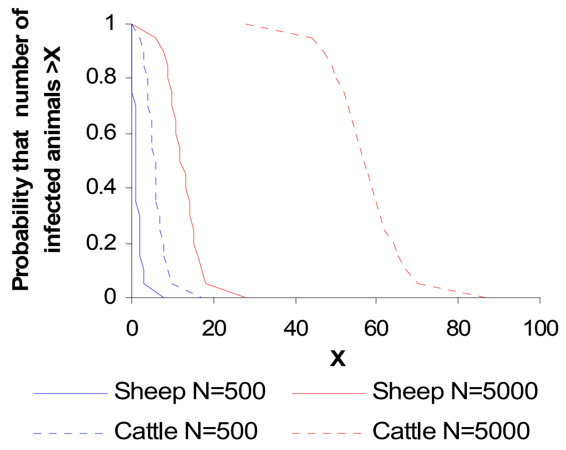

Figure 5
Expected number of viraemic cattle and sheep moved from uninfected free areas of Scenario B to areas free of bluetongue

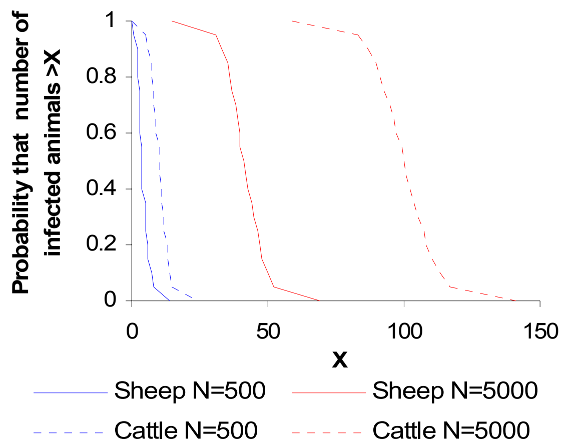

Figure 6
Expected number of viraemic cattle and sheep moved from uninfected free areas of Scenario C to areas free of bluetongue

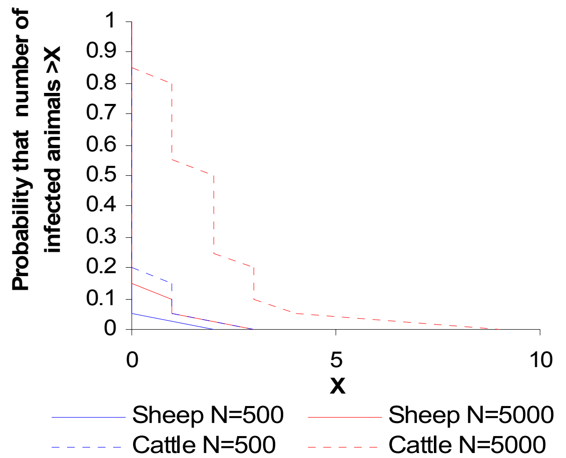

Figure 7
Expected number of viraemic cattle and sheep moved from uninfected free areas of Scenario A to areas free of bluetongue

Discussion

Risk analysis is recognised worldwide as a tool to assess risk associated with the international movement of animals (6). The same approach was applied in this study to the internal movement of domestic ruminants from areas in which movement restrictions were enforced due to the presence of bluetongue to areas free from infection. The results of the risk assessment described here were taken into account by the Italian General Directorate of Veterinary Services, which modified national veterinary legislation on movement bans from restricted zones.

The expected number of viraemic ruminants among animals from areas subjected to movement restrictions varies according to the level of vaccination in the population of the area of origin. When less than 80% of the domestic ruminant population of the area of origin is vaccinated, the risk of transferring a number of viraemic cattle sufficient to cause the spread of BTV to free areas is not negligible, even if other risk mitigation measures are applied. On the contrary, when more than 80% of the domestic ruminant population in the area of origin is vaccinated, the risk of spreading the infection by moving the animals to free areas is significantly lower. In the case of vaccinated cattle sent directly to slaughter, in particular if transfer occurs during daylight, the risk of infection spreading to the receiving free areas can be considered negligible. When the animals come from an area in which over 80% of the domestic ruminant population is vaccinated and there is no evidence of BTV circulation, the risk of BTV spread, due to cattle or sheep movement, can be considered absolutely negligible.

In the case of vaccinated sheep being moved from areas with no evidence of BTV circulation, irrespective of whether the 80% vaccination level in the domestic ruminant populations has been attained, the risk of spread of infection in the receiving free areas is virtually nil. This is especially true if the animals are sent directly to slaughter, preferably during daylight hours. The difference observed in the expected number of viraemic cattle compared to sheep is a consequence of the difference between the average monthly incidence of infection observed in previous years (input variables c and d), namely: 8.7% in cattle and 3.6% sheep.

A summary of the different modes of shipment of animals from areas in which vaccination is practised to infection-free unvaccinated areas, accompanied by suggested risk mitigation measures derived from the results of the risk assessment is given in Table I.

Table I
Possible trade patterns of animals from vaccinated areas to bluetongue-free areas and suggested risk mitigation measures

Origin of animals	Possibility of shipment of animals to free areas	Suggested risk mitigating measure(s)
Infected and uninfected areas of regions where **more than 80%** of the susceptible population is vaccinated	Yes	Movement of vaccinated animals only directly to slaughterhouse, preferably during daylight
Infected and uninfected areas of regions where **less than 80%** of the susceptible population is vaccinated	No	Not applicable
Uninfected areas only of regions where **more than 80%** of the susceptible population is vaccinated	Yes	Movement of vaccinated animals only
Uninfected areas only of regions where **less than 80%** of the susceptible population is vaccinated	Yes	Movement of vaccinated sheep only directly to slaughterhouse, preferably during daylight

References

1. Calistri P., Giovannini A., Conte A., Nannini D., Santucci U., Patta C., Rolesu S. & Caporale V. (2004). – Bluetongue in Italy: Part I. *In* Bluetongue, Part I (N.J. MacLachlan & J.E. Pearson, eds). Proc. Third International Symposium, Taormina, 26-29 October 2003. *Vet. Ital.*, **40** (3), 243-251.
2. Giovannini A., MacDiarmid S.C., Calistri P., Conte A., Savini L., Nannini D. & Weber S. (2003). – The use of risk assessment to decide the control strategy for bluetongue in Italian ruminant populations. *J. Risk Anal.*, **24** (6), 1737-1753.
3. Giovannini A., Calistri P., Nannini D., Paladini C., Santucci U. & Caporale V. (2004). – Bluetongue in Italy: Part II. *In* Bluetongue, Part I (N.J. MacLachlan & J.E. Pearson, eds). Proc. Third International Symposium, Taormina, 26-29 October 2003. *Vet. Ital.*, **40** (3), 252-259.
4. Ministero della Sanità (2001). – Ordinanza 11 maggio 2001. Misure urgenti di profilassi vaccinale obbligatoria contro la febbre catarrale degli ovini (Blue-tongue). *Gazz. Uff. Repubbl. Ital., Serie gen.*, **128**, 5 June, 43-44.
5. Ministero della Sanità (2001). – Ordinanza 11 maggio 2001. Misure urgenti di profilassi vaccinale

obbligatoria contro la febbre catarrale degli ovini (Blue-tongue), parte IV, allegato I (izs.it/bluetongue/ministero/hpage_file/spostamento_all_I_parte_V_rev2.pdf accessed on 12 September 2004).
6. Office International des Épizooties (OIE) (2003). – Terrestrial animal health code, 12th Ed. OIE, Paris (oie.int/eng/normes/mcode/A_summry.htm accessed on 14 August 2004).
7. Vose D. (2000). – Risk analysis: a quantitative guide, 2nd Ed. John Wiley & Sons, Chichester, 418 pp.