Veterinaria Italiana, **42** (3), 201-207

Development of a web-based geographic information system for the epidemiological surveillance of bluetongue in the Balkans and eastern Mediterranean countries

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Summary

Bluetongue (BT) is an infectious, non-contagious, arthropod-borne disease transmitted by biting midges. When BT spread throughout the Balkans (affecting Albania, Bosnia-Herzegovina, Bulgaria, Croatia, the Former Yugoslav Republic of Macedonia and Serbia and Montenegro), it caused serious concerns for veterinary authorities in all countries in the eastern Mediterranean. In 2003-2004 a web-based BT geographic information system network was developed and implemented to provide veterinary services with a tool to manage and analyse data on the disease and to exchange information. The system was centralised to ensure there was a common epidemiological surveillance strategy. Spatial and alphanumerical data on the disease were organised in a single relational geographic database. The system was equipped with a number of applications for the display of dynamic maps and data information via the web, with multi-user access for simultaneous queries from additional users.

Keywords

Balkans, Bluetongue, Geographic information system, Mediterranean Basin, Surveillance network, Web.

Introduction

Bluetongue (BT) is an infectious, non-contagious, arthropod-borne disease that is transmitted by biting midges of the genus *Culicoides*. Ruminants are susceptible to the infection, but the disease primarily affects sheep, with a mortality rate varying from 0 to 30% (1, 14).

Of the 1 254 species of *Culicoides* found worldwide, at least 30 appear to be involved in BT transmission (15). In the Old World which includes the Mediterranean Basin, the principal vector is *Culicoides imicola* Kieffer (1), a species first described in 1913 in East Africa, and shown subsequently in South Africa to be capable of transmitting bluetongue virus (BTV) (6).

In the Mediterranean region, BT was first reported from Cyprus and Israel in 1943, but it is thought to have occurred in the region as early as 1924 (11).

An extensive outbreak occurred in Spain and Portugal where BTV caused the death of approximately 179 000 sheep between 1956 and 1960 (14).

More recently, various BTV serotypes were incriminated in the Mediterranean epidemics, the most predominant of which were BTV-2 (Algeria, Balearic Islands, Corsica, Italy, Tunisia), BTV-4 (Greece, Italy, Morocco, southern Spain and Portugal), BTV-9 (Albania, Bosnia-Herzegovina, Bulgaria, Croatia, Former Yugoslav Republic of

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Macedonia, Greece, Italy, Serbia and Montenegro, Turkey) and BTV-16 (Corsica, Greece, Italy, Turkey) (12). Direct losses in the Balkan and eastern Mediterranean regions, due to the death of diseased animals, were relatively low due to the reduced pathogenicity of the serotypes involved. However, countries affected by BTV outbreaks suffered from trade restrictions of cattle and sheep because sales and movements of animals were banned (8, 9, 16). Being a vector-borne disease, BT cannot be prevented through an animal trade control policy alone; individual national measures tend to be inadequate to face a transboundary phenomenon such as BT. At present, the Balkan countries have not established a common strategy or implemented intra-regional activities that will be able to tackle BT spread globally. Therefore, between 2003 and 2005, a bluetongue surveillance network (BTNet), covering the Balkan area, was implemented by the World organisation for animal health (OIE: Office International des Épizooties) Collaborating Centre for veterinary training, epidemiology, food safety and animal welfare of the Istituto Zooprofilattico dell'Abruzzo e del Molise 'G. Caporale' (OIE CC-IZSA&M). The information network, based on internet links and on geographic information system (GIS) website technologies, enables the immediate recording, exchange and analysis of information relevant to BT epidemiology (5). This paper describes the development of the web-GIS section, the key functions of which are to collect and manage BTV data and to rapidly generate maps on BTV spread in the Balkans.

Materials and methods

The website is accessible through a generic internet browser. Two servers were used to host all GIS applications and functions (Fig. 1), as follows:

- a GIS server which collects ArcIMS™ 3.1 (Environmental Systems Research Institute Inc.: ESRI) projects developed using an html viewer customisation for publishing maps, data, images and Java™ script pages (JSP) (10, 17). The server is an HP NetServer LXr 8500, with four 700 MHz microprocessors and 2 GB of RAM

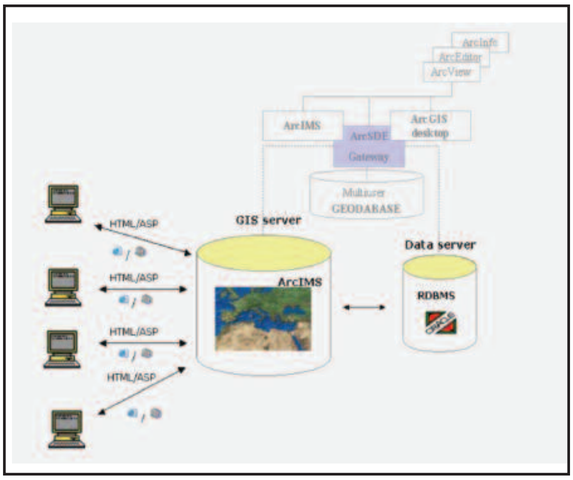

Figure 1
Functional and logical architecture of the BTNet website – 'maps' section

- a data server containing ArcSDE™ (ESRI) and an Oracle™ relational database management system (RDBMS) where spatial and alphanumerical data are stored. ArcSDE™, the gateway between ArcIMS™ and RDBMS, is used to share and manage the spatial data and to optimise simultaneous access to the geographic features by several users (17).

The server is a Proliant DL580 G2, with four 2.8 GHz microprocessors and 4 GB of RAM.
Information was collected from serological and entomological national surveillance programmes implemented by participating countries (Fig. 2) and from data released weekly by the OIE (www.oie.int/eng/info/hebdo/A_info.htm).
The system is entirely automatic and can be accessed, as far as the 'serological and entomological surveillance' sessions is concerned, by authorised users through an electronic authentication procedure,

Figure 2
Countries participating in the project for the implementation of a bluetongue surveillance network

after supplying a username and password. The 'disease distribution' provides free access without authorisation. At present, a total of 32 users are authorised to access the system, 25 of whom are the officially designated users from the participating countries. The user inputs new information and data on his/her geographic area of competence directly on-line using active server pages (.asp) and a web interface.

The accuracy of data entered into the information system is guaranteed by automatic check procedures (e.g. missing values, duplicates, incorrect data format, etc.) that operate during the updating of the centralised database.

The interactive thematic maps are equipped with several standard ArcIMS™ tools (zoom in/out, pan) and query functions (identify, query, find, select).

Features in the maps may correspond to a polygon (regions, provinces or an administrative boundary) or to a point when the geographical coordinates of the site are available. The geographic elements are linked to the alphanumerical components stored in the geographical database through a spatial query (Fig. 3).

Newly entered data are displayed in map format. Updating of layers with new features (e.g. addition of a new point on the map) is performed immediately once the authorised user inputs new data.

Multi-user access is obtained through the creation of 10 parallel sessions managed by Java™ scripts. Multi-user access management enables personalised queries of the alphanumerical section and relevant map displays.

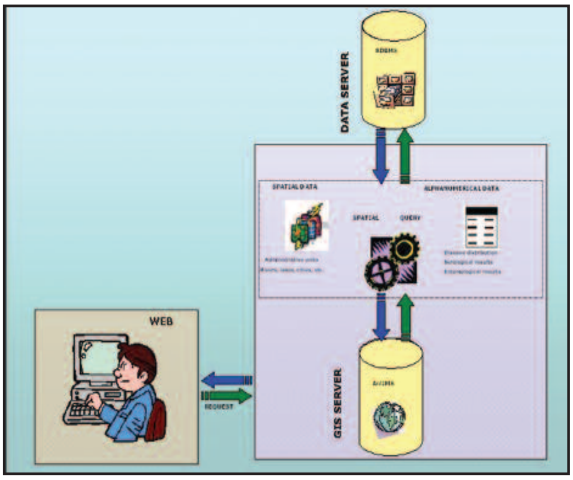

Figure 3
Interactions between spatial and alphanumerical data through spatial queries

Results

Data shown in Figures 4, 5, 6, 7 and 8 are not real and have been used for explanatory purposes only.

Three different ArcIMS™ services were created representing three principal sets of information, as follows:

Disease distribution

The annual geographical distribution of BTV serotypes retrieved from the OIE is represented in this section. The OIE CC-IZSA&M is responsible for constantly updating the system; new data are entered directly online after selecting the relevant administrative boundary (Fig. 4A). The system checks the accuracy of new data before updating the database (Fig. 4B). New information is automatically displayed on the map by simply refreshing the screen (Fig. 4C).

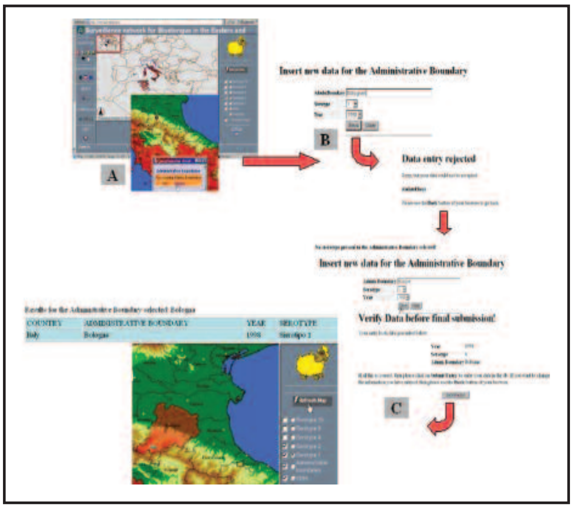

Figure 4
Disease distribution section
Procedure for data display (A) and update (B and C)

Serological surveillance

Figure 5 illustrates data access and updating of the data server. The map has an optional function for the selection by period and animal species. A dynamic map is displayed and the user can surf alphanumerical and geographical data according to his/her specific request (Fig. 5A). Authorised users can update the serological data online as shown in the form in Fig. 5B; the new information is displayed after refreshing the screen (Fig. 5C). Data recorded are as follows: number of tested animals, number of positive animals and diagnostic tests used for each year, month, species and geographic unit (administrative boundary).

Entomological surveillance

The results of *Culicoides* trapping activities can be viewed in this section. As for serological surveillance,

Figure 5
Serological surveillance section
Procedure for data display (A) and update (B and C)

authorised users update the entomological data directly. The following data is recorded: ID code and localisation (geographical coordinates) of catch, date of insect collections, number of *Culicoides* trapped sorted by species (*C. imicola*, Obsoletus Complex, Pulicaris Complex), minimum and maximum temperatures recorded during the trapping nights. Information on catch results may be retrieved for specific catching sites (Fig. 6A) and/or for a selected geographical unit (Fig. 6B). In order to improve the quality of data, specific procedures have been implemented for:

- the retrieval of ID codes catching sites when already present in the database, thus reducing errors (Figs 7A and 7B)
- the validation of catching sites coordinates (registered coordinates must fall within the rectangular area of the declared geographic unit of reference) (Fig. 7C).

Several tools are available in all map sessions (select, query, identify, find and buffer). The buffer tool is particularly useful to veterinary services for planning activities in areas where bluetongue

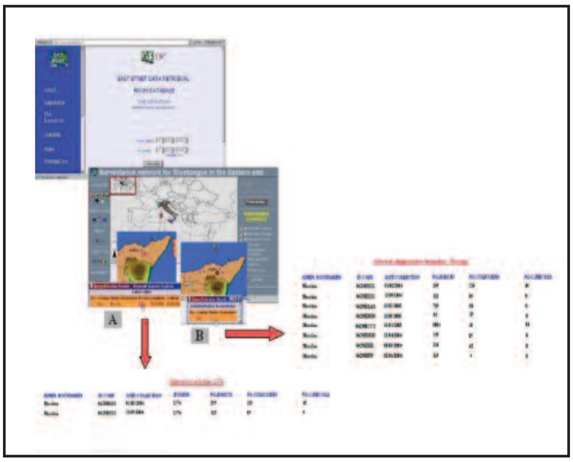

Figure 6
Entomological surveillance section
Procedures for displaying data for each selected *Culicoides* catch site (A) or geographic unit (B)

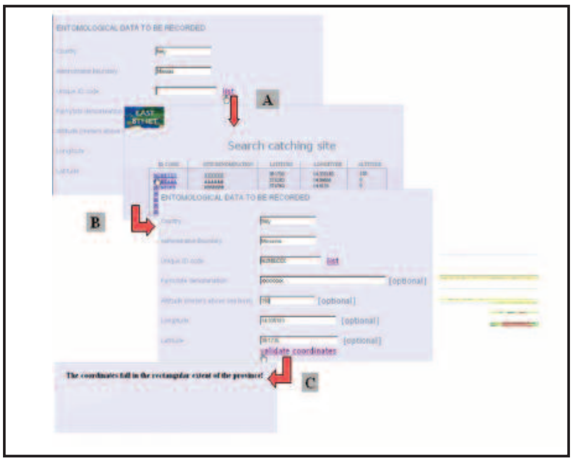

Figure 7
Entomological surveillance section
Procedures for the retrieval of the ID code for catch sites A and B from a list of sites already recorded in the system, and for the validation of geographic coordinates of site C

vectors have been identified (Fig. 8). The system enables the construction of a buffer around a given point or an infected area and the retrieval of the list of geographic units within the defined buffer zone and the related epidemiological data (catch sites, date of insect collections, number of *Culicoides*

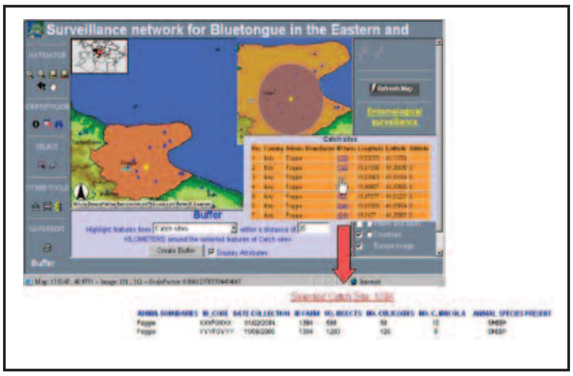

Figure 8
Entomological surveillance section
Example of the use of the buffer tool

trapped sorted by species etc.), thus allowing veterinary services to obtain timely and useful information for the control of the disease.

Discussion

To better understand the importance of BT in the Balkans, the total ruminant population in the region is about 18 million sheep and goats and 7 million cattle. Besides direct losses inflicted by the disease on sheep breeders, the unavoidable restrictions on ruminant movements may be very detrimental to the economy of countries in the region. Vector-borne diseases, such as BT, cannot only be prevented through trade control measures and a common approach to the surveillance of the disease is necessary to adequately face the spread of infection. Therefore, the implementation of a BT surveillance network throughout the area responds to the need for a more homogeneous and coordinated approach to BT surveillance.
The surveillance network was established with a large use of GIS technologies for data analysis and for exchanging relevant epidemiological information.
The establishment and implementationof a common GIS network generates rapid and easy data distribution. Being able to consult regularly

updated data so rapidly is invaluable for decision-making processes and provides the different actors involved with a tool that offers the latest information on a given epidemiological situation. In particular, BTNet enables the following:

- preparation of standardised procedures for data collection relevant to vectors and BT geographical distribution and for epidemiological data analysis
- definition of common criteria for the implementation of national surveillance systems and early warning systems
- elaboration of standards.

In animal health, as is the case in public health, an exploratory, visual and intuitive approach to data on the infection under study and the use of GIS enables the analysis of information at several levels of aggregation, thus providing a wider and more complete picture of the phenomenon under study (3, 13).

The development of web-based GIS applications in the veterinary field has led to the collection and dissemination of information on several infectious diseases (2, 4, 7). More extensive use at the international level (i.e. European Commission, OIE) of this type of web-based geographic interface system, is desirable and will provide useful tools to perform spatial analysis.

Acknowledgements

The authors would like to thank the representatives of the countries involved in the project (Albania, Bosnia-Herzegovina, Bulgaria, Croatia, Cyprus, Former Yugoslav Republic of Macedonia [FYROM], Malta, Serbia and Montenegro, Romania, Slovenia and Turkey) for their valuable contribution to the achievement of the objectives set by the project. The authors are also extremely grateful to Sandro Pelini and Angela De Dominicis for their assistance.

Grant support

The activities described in this paper were performed as part of the 'Cooperation for implementing a surveillance network for bluetongue in the Balkanic area' (BTNet) project, promoted by the Region of Abruzzo in Italy and funded by the Italian Ministry of Foreign Affairs, under the provisions of Law No. 84 of 21 March 2001 concerning Italian cooperation in the Balkans.

References

1. Calistri P., Goffredo M., Caporale V. & Meiswinkel R. 2003. The distribution of *Culicoides imicola* in Italy: application and evaluation of current Mediterranean models based on climate. *J Vet Med B*, **50** (3), 132-138.
2. Cameron A.R. 2004. Data management and analysis systems for bluetongue virus zoning in Australia. *In* Proc. Third International Symposium, 26-29 October 2003, Taormina, Part I (N.J. MacLachlan & J.E. Pearson, eds). *Vet Ital*, **40** (3), 365-368.
3. Clarke K.C., McLafferty S.L. & Tempalski B.J. 1996. On epidemiology and geographic information systems: a review and discussion of future directions. *Emerg Infect Dis*, **2** (2) (www.cdc.gov/ncidod/eid/vol2no2/clarke.htm accessed on 6 April 2006).
4. Conte A., Colangeli P., Ippoliti C., Paladini C., Ambrosiani M., Savini L., Dall'Acqua F., Calistri P. (2005). The use of a web-based interactive geographical information system for the surveillance of bluetongue in Italy. *Rev Sci Tech*, **24** (3), 857-868.
5. Dall'Acqua F., Paladini C., Meiswinkel R., Savini L. & Calistri P. 2006. Description and implementation of surveillance network for bluetongue in the Balkan Region and in adjoining areas of south-eastern Europe. *Vet Ital*, **42** (2), 103-118.

6. Du Toit R.M. 1944. The transmission of bluetongue and horse-sickness by *Culicoides*. *Onderstepoort J Vet Sci An Ind*, **19**, 7-16.
7. Egbert M. 2004. Web-based disease tracking: a West Nile virus example. *In* Proc. 2004 ESRI International User Conference, 9-13 August, San Diego. Environmental Systems Research Institute, Redlands, California (gis.esri.com/library/userconf/proc04/docs/pap1131.pdf accessed on 4 May 2006).
8. European Commission 2001. Decision of 9 November 2001 on protection and surveillance zones in relation to bluetongue, and on rules applicable to movements of animals in and from those zones (2001/783/EC). *Off J*, **L 293**, 10/11/2001, 42-46.
9. European Council 2000. Directive 2000/75/EC of 20 November 2000 laying down specific provision for the control and eradication of bluetongue. *Off J*, **L 327**, 74-83.
10. Flanagan D. 2001. JavaScript: the definitive guide, Fourth Ed. O'Reilly Media, Inc., Sebastopol, California, 900 pp.
11. Gambles R.M. 1949. Bluetongue of sheep in Cyprus. *J Comp Pathol*, **59**, 176-190.
12. Gómez-Tejedor C. 2004. Brief overview of the bluetongue situation in Mediterranean Europe, 1998-2004. *In* Proc. Third International Symposium, 26-29 October 2003, Taormina, Part I (N.J. MacLachlan & J.E. Pearson, eds). *Vet Ital*, **40** (3), 57-60.
13. Goodchild M.F. 1998. Strategies for GIS and public health. *In* Proc. Third National Conference on Geographic information systems in public health, 18-20 August, San Diego (R.C. Williams, M.M. Howie, C.V. Lee & W.D Henriques, eds). Agency for Toxic Substances and Disease Registry/Centers for Disease Control, San Diego, 63-71 (www.atsdr.cdc.gov/gis/conference98/proceedings/pdf/gisbook.pdf accessed on 6 April 2006).
14. Manso-Ribeiro J., Rosa-Azevedo J.A., Noronha F.O., Braco-Forte M.C., Grave-Pereira C. & Vasco-Fernandez M. 1957. Fièvre catarrhale du mouton (bluetongue). *Bull Off Int Epiz*, **48**, 350-367.
15. Meiswinkel R., Gomulski L.M., Delécolle J.C., Goffredo M. & Gasperi G. 2004. The taxonomy of *Culicoides* vector complexes – unfinished business. *In* Proc. Third International Symposium, 26-29 October 2003, Taormina, Part I (N.J. MacLachlan & J.E. Pearson, eds). *Vet Ital*, **40** (3), 151-159.
16. Panagiotatos D.E. 2004. Regional overview of bluetongue viruses, vectors, surveillance and unique features in Eastern Europe between 1998 and 2003. *In* Proc. Third International Symposium, 26-29 October 2003, Taormina, Part I (N.J. MacLachlan & J.E. Pearson, eds). *Vet Ital*, **40** (3), 61-72.
17. Zieler M. 1999. Modeling our world: the ESRI guide to geodatabase design. Environmental Systems Research Institute, Redlands, California, 200 pp.