The use of a Web-based interactive Geographical Information System for the surveillance of bluetongue in Italy

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Summary
Since 2000 Italy has experienced five epidemics of bluetongue, an arthropod-borne disease that affects primarily sheep and asymptomatically cattle, goats and wildlife ruminants. In four years the disease spread through Southern and Central Italy, involving 14 Italian regions out of 20. To control the disease, the Ministry of Health established a surveillance system that included clinical, entomological and serological surveillance elements. The National Reference Centre for Veterinary Epidemiology – Istituto Zooprofilattico Sperimentale dell’Abruzzo e del Molise ‘G. Caporale’ – developed a Web-based National Information System (NIS) and a Geographical Information System (GIS) to collect and manage data from Veterinary Services across Italy. The system was designed to gather and spread information in order to support the management of control activities and to provide an early warning system. Surveillance data are displayed to the user in different ways: reports, tables and interactive maps.

Keywords

Introduction

As far as Italy is concerned, the disease has caused significant losses in terms of both dead or slaughtered animals (more than 600,000 sheep and goats) and heavy economic losses due to trade restrictions on ruminants (3, 11). The losses were particularly heavy in the first two epidemics (from August 2000 to April 2002).
In May 2001, the Ministry of Health, which is responsible for the Italian Veterinary Services (VSs), implemented a surveillance system (12) based on clinical, entomological and serological surveillance plans, in order to:

a) verify the presence of clinical symptoms where the disease was suspected

b) detect and constantly monitor the presence/absence of BTV throughout all of Italy by the periodic testing of more than 30,000 sentinel animals

c) evaluate the risk linked to:

– the presence, abundance and seasonal dynamics of C. imicola (using more than 250 permanent black-light traps all over Italy) (6)

– the possible role of other biting midges belonging to the genus Culicoides.

The Italian National Reference Centre for Veterinary Epidemiology (COVEPI) produces weekly analyses of the data collected by regional veterinary laboratories (Istituti Zooprofilattici Sperimentali [IZSs]) and the VSs. It also supplies all the necessary information to the Ministry of Health so that the Ministry can apply the restriction measures authorised by current legislation.

In order to collect and manage the large amount of data gathered in the surveillance activities, the COVEPI developed a Web-based National Information System (NIS) (12) in 2001. A second version of the NIS was implemented and put in place in June 2004. A large Web-enabled Geographic Information System (GIS) was added to analyse BT epidemiological data and to present the results in a user-friendly format. The developed Web-GIS system provides both decision-makers and stakeholders (VSs, farmers, slaughterhouses, etc.) with a powerful tool to integrate data deriving from different sources. Moreover, the system allows information to be rapidly spread by displaying data and providing explorative analysis tools.

The aim of the paper is to briefly summarise the working of the NIS, which has already been described elsewhere (12), and to give detailed information on the new Web-enabled GIS.

Materials and methods

System architecture

The NIS was designed and implemented in a generic browser utilising the Oracle9i Application Server (9iAS). The system is accessible at: http://gs2.izs.it:7777/pls/izs_btv/btv_gestmenu.btv_index.

The architecture of the system is characterised by the interconnection of three different servers:

a) a Web server, where images and Java™ script pages (JSP) are located. The server used for this purpose is an HP NetServer LXr 8500, equipped with 4,700-MHz microprocessors and a RAM with a capacity of 2 gigabytes

b) a data server, containing ArcSDE (Environmental Systems Research Institute, Inc. [ESRI]) and an Oracle relational database management system (RDBMS) where all instructions to upload and download files and the PL/SQL batch procedures are recorded. The server is a Proliant DL580 G2, with four 2.8-GHz microprocessors and 4 gigabytes of RAM

c) a GIS server, where ArcIMS™ 3.1 (ESRI) projects for presentation of maps are stored. The server is an HP NetServer LXr 8500, with four 700-MHz microprocessors and 2 gigabytes of RAM.

Data collection and data flow

The surveillance system is based upon daily:

a) recordings of all suspected and confirmed BT clinical cases

b) recordings of the results of periodic testing of sentinel animals; sentinel animals are tested fortnightly through c-enzyme-linked immunosorbent assay (ELISA). Seroconversion is confirmed by a serum neutralisation test in the event of a c-ELISA positive response

c) reports on monitoring of the spread of vectors and their seasonal dynamics

d) recordings of all diagnostic results

e) recordings of the progress of vaccination campaigns.

Data about the results of serological tests (points b and d above) come from the ten Italian IZSs, while notification of new outbreaks (point a) and data about the vaccination campaigns (point e) come from the VSs of the infected regions. The National Reference Centre for Exotic Diseases provides results of virological tests and information on the distribution and abundance of Culicoides catches. Each night, a batch procedure updates the information in the central database.

In the first version of the NIS, data collected were recorded on the local databases of IZSs or VSs (using a specific software developed to ease data entry and retrieval in a standard format) and sent weekly by e-mail to the NIS. The second version replaced the use of e-mail with a Web-interfaced file for uploading or directly on-line updating of a single record entry. All data gathered are automatically checked for errors (missing values, duplicates, wrong data format, etc.) and the users are informed about the result of the uploading by an e-mail message reporting either the number of records updated or the number of incorrect records.
Data access

The NIS includes both pages that are freely accessible to the public and restricted sections, accessible only to the General Directorate of VSs, IZSs and official veterinarians of VSs.

The free-access sections of the NIS Web site provide:
- informative pages describing the disease
- a collection of technical and scientific documents (inspection reports, risk analysis papers, etc.)
- a complete archive of national and European Union legal provisions on BT
- a list of infected territories (municipalities), with both reports and maps
- thematic maps showing the results of the entomological and serological surveillance activities and the vaccination status of the animal population (see the GIS section below for details)
- tables and reports summarising the number of clinical outbreaks and vaccinated animals in different epidemics
- PowerPoint® presentations displaying a synthesis of the serological and entomological surveillance results.

Restricted data in the NIS are accessed by login name and password. Each user can access only data relevant to the geographic area for which he or she is responsible, while the System Administrator, the COVEPI and the General Directorate of VSs have full access to the database. Users may also have special permissions to access specific data, depending on their positions and responsibilities.

Geographical Information System

The Web-based GIS application was developed through the use of ArcIMS 3.1™ with an HTML viewer customisation. ArcIMS is a server-based product that provides a scalable framework for distributing GIS services and data over the Web. Themes displayed on the maps are generated either weekly, by ArcInfo Arc Macro Language (AML) macros, or in real time with the aid of ArcSDE™ ESRI, a server software product used to access large, multi-user geographic databases stored in Oracle RDBMS. Oracle tables are updated nightly by batch procedures.

The interactive thematic maps, standard ArcIMS browsing functions (zoom in, zoom out, pan) and query functions (hyperlinks, identifier, query) show the epidemiological situation in terms of:

a) BT clinical outbreaks in sheep and goat flocks detected in the last 60 days of epidemics
b) sentinel herds where at least one animal has seroconverted to BTV in the last 60 days
c) infected areas, defined as all the municipalities whose boundaries intersect a 20-km radius buffer from an infected holding (clinical outbreak or sentinel animal seroconversion) where the circulation of BTV has been detected in the last 60 days. The infected holding is identified by its latitude and longitude, when provided, or by the administrative boundary of its municipalities
d) the sites where entomological activities have been carried out in the last 12 months, using either permanent (always located on the same farm) or mobile (catching insects on different farms) black-light traps
e) progress made in vaccination activities in terms of the percentage of vaccinated animals in each Italian province.

Layers displayed on the maps correspond to point features, when the geographical coordinates of the farm are available, and to polygon features (representing the municipality where the infected farm is located) where the coordinates are not available. The geographic elements are linked to the alphanumerical component stored in the NIS database through the ‘hyperlink’ ArcIMS tool. The hyperlink makes possible a dynamic interaction between the epidemiological information and the geographical elements. The GIS navigation tool permits the user to query and retrieve data by simply clicking on the map.

Before October 2003, measures to verify evidence of BTV transmission took into account data from a 100-day infective period, as laid down in the Terrestrial Animal Health Code of the OIE (World Organisation for Animal Health). However, the third international symposium on BT of the OIE, held in Taormina (Italy) in October 2003, concluded that the infective period lasts not longer than 60 days (details are available at: http://www.bluetongue_symposium.it/conclusions.htm). This conclusion led to the decision to represent data about BTV transmission (clinical outbreaks and seroconverted sentinel animals) over a period not longer than 60 days.

Results

The system architecture is displayed in Figure 1, which shows the information flows among servers and clients. The GIS section includes 30 maps displaying information about the geographical distribution of:
- BT clinical outbreaks in sheep and goat flocks detected in the last 60 days (Fig. 2). The hyperlink tool allows the user to select a single outbreak and to view its identification data (farm code, owner name, address, etc.). The system can also show the number of live, diseased, dead and slaughtered animals recorded during each visit of the VSs (Fig. 3). The registration of these data permits the automatic creation of notification messages to be sent to
Fig. 1
System architecture

Fig. 2
Example of geographical distribution of clinical outbreaks during the fifth epidemic

Fig. 3
Example of hyperlink and database information for a clinical outbreak
veterinary international authorities (competent services of the European Commission and the OIE) by the Italian General Directorate of VSs

- infected zones, derived from the buffering procedures around infected holdings (Fig. 4)

- sentinel herds where at least one animal seroconverted in the last 60 days (Fig. 5). The hyperlink makes it possible to select a single herd and access the results of all epidemiological surveillance activities carried out in that specific farm: vaccination, clinical visits, laboratory tests, entomological surveys and outbreak data (Fig. 6). The tool used to create buffers helps the user to immediately identify the area surrounding the infected holding and to have a clear picture of where BT control measures must be applied (Fig. 7)

- the sites where entomological activities were carried out in the last year using permanent black-light traps (at least one in each Italian province) and mobile black-light traps (used for ad hoc surveys) (Fig. 8). Each map reports the presence/absence of C. imicola in each month of the past year. Another map summarises activities over that period. The hyperlink tool enables the user to obtain detailed information on each Culicoides catch performed in a specific holding

- vaccination campaigns: the percentage of vaccinated animals in each province. The hyperlink tool enables the user to view a detailed table for each province, displaying the percentage of vaccinated animals of different species and the vaccine serotypes used (Fig. 9).

Discussion

Since 2000, when BT first appeared in Italy, the infection has gone beyond its traditional boundaries, reaching latitude 44°N. The European Union, aware of the infectiousness of the disease, has imposed specific provisions for the control and the eradication of BT (9).

To this end, a surveillance system was designed in Italy to meet any need arising anywhere in the country promptly and efficaciously. The system involved the periodical testing of about 30,000 sentinel animals and the installing of over 250 permanent black-light traps for entomological surveillance, generating vast amounts of data. The central veterinary authorities responsible for controlling the disease required fast and easy access to this information, because the success of a surveillance plan depends on the ability of VSs to react in real time to the evolution of the disease and implement the correct control and eradication measures.

The first BT information system, developed in 2001, did not have dynamic map tools that would allow external users to interact with spatial data. The current version of the system, instead, has interactive geographical data analysis tools that allow direct access to maps showing information that is updated every day. In addition, external users can make specific spatial queries and retrieve data according to their needs (e.g., the possibility of creating buffers and identifying municipalities in the infected zone, or identifying municipalities to be controlled in any buffer radius). The constant upload via the Internet has guaranteed a smoother data collection flow and more reliable access for users.

The NIS provides VSs with updated epidemiological data on the BT situation, and with technical instruments for defining geographical zones where specific control measures, based mainly on vaccination and restrictions on animal movements, need to be applied. The real-time interactive mapping system of the main epidemiological aspects increases the efficiency of the entire system, allowing easier data management. Information generated by the NIS and spread via the Internet provides a common resource to facilitate decision-making processes and management of control activities at central and local levels. This sophisticated and sensitive system also provides a useful tool to verify the consistency and the efficacy of control actions taken by the competent authorities. For instance, the central Veterinary Authority continuously monitors the progress of the vaccination campaign in each Italian province and then identifies areas where corrective action is needed.

Breeders too gain benefits from the Web-enabled system. They can, for example, verify the BT sanitary status of the geographical areas where they need to introduce or move animals.

In contrast to many existing applications in health and human services (1, 2, 7, 29), the NIS is one of the few examples available so far of Web-based map services that contain GIS functionalities (5, 8, 13) for veterinary epidemiology and surveillance activities. The level of interest in these interactive systems is proved by the high number of connections, in terms both of single visitors and of downloaded pages, registered since June 2004 (Fig. 10). Visits to the Web site services are concentrated in the first two days of the week (54.3% of pages are downloaded on Monday or Tuesday), when the updated list of infected municipalities is published on the Web.

In assessing who makes most use of the system, two points should be borne in mind. First, veterinary officers need to know the infected status of a territory when deciding whether to impose restrictions on movement of animals, as authorised by European and national legislation. Second, specific and detailed knowledge of the BT surveillance system is needed in order to consult the GIS pages. Thus, it may be inferred that the majority of the clients of the
Fig. 4
Example of geographical distribution of infected municipalities

Fig. 5
Example of geographical distribution of municipalities with positive sentinel farms for bluetongue virus
Fig. 6
Example of hyperlink to (A) and navigation through (B) sentinel herd data
Fig. 7
20-km buffer around a seroconverted farm and definition of infected municipalities

Fig. 8
Entomological surveillance plan: distribution of catch results
system are public veterinary officers (some of the 5,500 or so public veterinarians [10] employed in different fields — food safety, animal health and welfare, and the hygiene of animal breeding and products).

It should be noted that while the Web-GIS system has made the spreading of information faster and easier, it entails considerable costs in human and financial resources. Developing an accurate and complete system is a complex engineering process that starts with a careful analysis of needs and information to be collected and ends with the application of new technologies. Sufficient financial resources, then, are needed to train people and retain technical expertise, to buy the necessary hardware and software for data analysis and to improve network services via the Internet. The amounts of financial and human resources required depend heavily on the complexity of the project and the amount of data to be managed.

Costly though such systems may be, the flexibility of these tools (ranging from the simplest to the most advanced and customised services) makes it possible to develop applications suitable to any geographical context and to any disease where the spatial component plays a fundamental role.
Utilización de un sistema de información geográfica por Internet para la vigilancia de la lengua azul en Italia

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Resumen
Desde el año 2000, Italia ha conocido cinco epizootias de lengua azul, enfermedad transmitida por artrópodos que afecta principalmente a los ovinos y, de forma asintomática, a bovinos, caprinos y rumiantes salvajes. En cuatro años esa dolencia se extendió por el sur y el centro del país, afectando a 14 de las 20 regiones italianas. Para luchar contra ella, el Ministerio de Salud instituyó un sistema que integraba elementos de vigilancia clínica, entomológica y serológica. A fin de reunir y tratar datos procedentes de Servicios Veterinarios de todo el país, el Istituto Zooprofilattico Sperimentale dell’Abruzzo e del Molise ‘G. Caporale’, centro de referencia nacional de epidemiología veterinaria, creó
un sistema nacional de información y otro de información geográfica que funcionaban desde un sitio web. El sistema fue concebido para centralizar y difundir información con objeto de apoyar la gestión de las actividades de lucha y de constituir un sistema de alerta rápida. El usuario puede consultar los datos de vigilancia presentados como informes, cuadros o mapas interactivos.

**Palabras clave**

Lengua azul – Sistema de información geográfica – Sistema de vigilancia – Internet.

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**References**


