The Arbo-zoonet Information System

Alessio Di Lorenzo*, Daria Di Sabatino, Annamaria Conte, Daniela Cioci, Rossana Bruno, Paolo Calistri & Lara Savini

Istituto Zooprofilattico Sperimentale dell'Abruzzo e del Molise 'G. Caporale', Teramo, Italy

** Corresponding author at: Istituto Zooprofilattico Sperimentale dell'Abruzzo e del Molise 'G. Caporale', Campo Boario, 64100 Teramo, Italy. Tel.: +39 0861 332248, e-mail: a.dilorenzo@izs.it.*

Veterinaria Italiana 2016, **52** (2), 161-168. doi: 10.12834/VetIt.522.2484.1
Accepted: 11.11.2015 | Available on line: 30.06.2016

Keywords
Crimean-Congo haemorrhagic fever,
Data sharing,
Disease,
Epidemic emergency,
Geographic disease distribution,
Rift Valley fever,
Schmallenberg virus,
Spatial database,
WebGIS,
West Nile Disease.

Summary
The Arbo-zoonet Information System has been developed as part of the 'International Network for Capacity Building for the Control of Emerging Viral Vector Borne Zoonotic Diseases (Arbo-zoonet)' project. The project aims to create common knowledge, sharing data, expertise, experiences, and scientific information on West Nile Disease (WND), Crimean-Congo haemorrhagic fever (CCHF), and Rift Valley fever (RVF). These arthropod-borne diseases of domestic and wild animals can affect humans, posing great threat to public health. Since November 2011, when the Schmallenberg virus (SBV) has been discovered for the first time in Northern Europe, the Arbo-zoonet Information System has been used in order to collect information on newly discovered disease and to manage the epidemic emergency. The system monitors the geographical distribution and epidemiological evolution of CCHF, RVF, and WND since 1946. More recently, it has also been deployed to monitor the SBV data. The Arbo-zoonet Information System includes a web application for the management of the database in which data are stored and a WebGIS application to explore spatial disease distributions, facilitating the epidemiological analysis. The WebGIS application is an effective tool to show and share the information and to facilitate the exchange and dissemination of relevant data among project's participants.

Il sistema informativo Arbo-zoonet

Parole chiave
Banca dati spaziale,
Condivisione di dati,
Crimean-Congo haemorrhagic fever,
Distribuzione geografica delle malattie,
Emergenze epidemiche,
Malattie,
Rift Valley fever,
Schmallenberg virus,
WebGIS,
West Nile Disease.

Riassunto
Il sistema informativo Arbo-zoonet è stato sviluppato come parte del progetto " International Network for Capacity Building for the Control of Emerging Viral Vector Borne Zoonotic Diseases (Arbo-zoonet)". Il progetto si propone di creare conoscenza comune, condivisione e scambio di dati, competenze e informazioni scientifiche su West Nile Disease (WND), Crimean-Congo haemorrhagic fever (CCHF) e Rift Valley fever (RVF). Si tratta di malattie trasmesse da vettori che colpiscono gli animali domestici e selvatici e possono infettare anche l'uomo, per cui rappresentano una grande minaccia per la salute pubblica. Dopo che nel Novembre del 2011, il virus Schmallenberg si è presentato per la prima volta nel nord Europa colpendo: Belgio, Germania, Francia, Italia, Lussemburgo, Olanda, Spagna, e Inghilterra, il sistema informativo Arbo-zoonet è stato utilizzato per la raccolta delle informazioni sulla nuova infezione emergente e per la gestione dell'emergenza epidemica. Il sistema mostra la distribuzione geografica e l'evoluzione temporale delle epidemie di CCHF, RVF, WND e SBV. Il sistema informativo Arbo-zoonet comprende un'applicazione web per la gestione on line del database per raccogliere, memorizzare e gestire i dati e un'applicazione WebGIS finalizzata a mostrare la distribuzione spaziale dei dati relativi alle malattie per favorire l'analisi epidemiologica. L'applicazione WebGIS è uno strumento efficace per mostrare e condividere le informazioni sul web e per facilitare lo scambio e la diffusione di dati rilevanti tra i partecipanti al progetto.

Introduction

Vector-borne diseases are an emerging sanitary threat for the Mediterranean Basin and the neighbouring countries (Chevalier *et al.* 2004). They cannot be prevented only through animal trade control policies and they can easily spread across different countries or continents. Recent outbreaks have clearly indicated the necessity for a trans-boundary and international approach to their surveillance and control (Kortekaas *et al.* 2010).

West Nile disease (WND), Crimean-Congo haemorrhagic fever (CCHF), and Rift Valley fever (RVF) are all arthropod-borne diseases of domestic and wild animals that can affect humans, posing a great threat to public health due to their epidemic and zoonotic potential. Their geographical distribution has greatly expanded in recent decades, gained interest and relevance in the light of the global warming (Ahmed *et al.* 2009).

West Nile disease is one of the arboviruses most extensively distributed worldwide, being present on all continents except Antarctica. Since the 1990s, a constant increase in the number of epidemics in the Mediterranean basin has been registered (Murgue *et al.* 2001, Calistri *et al.* 2010). In Italy alone, in August 2008 WND infection re-emerged in Northern part of the country, where 9 human cases were detected, 4 of which characterised by neuroinvasive symptoms. In the following years, new epidemics re-emerged in the same area, and new foci of infection were observed in Central and Southern Italy. In 2010, for the third consecutive year, human cases of West Nile infection, including 3 confirmed cases of neuro-invasive disease, and 3 confirmed cases of West Nile fever, were identified in North-Eastern Italy (Calistri *et al.* 2010, Barzon *et al.* 2013, Bagnarelli *et al.* 2011).

Crimean-Congo haemorrhagic fever is the most widespread viral zoonosis transmitted by ticks, it is endemic in many countries in Africa, Europe and Asia. Since 1999, cases or outbreaks have been recorded in Kosovo, Albania, Bulgaria, Greece, Iran, Pakistan, South Africa, and the Southern Federal Districts of Russia as well as in Turkey (Ahmed *et al.* 2009, Mild *et al.* 2010).

Rift Valley fever has been never introduced into Europe, but it is considered a major threat for North African countries. According to the high numbers of competent vector species present in disease-free regions, the intensification of international trade in live animals, and the uncertain effects of climate change, the RVF is now considered a major challenge in global zoonotic disease control (Pepin *et al.* 2010).

Schmallenberg virus has been identified in Germany in November 2011 (Hoffmann *et al.* 2012). It belongs to the family *Bunyaviridae*, genus *Orthobunyavirus*. The infection is considered as non-contagious, most likely it spreads among ruminants by biting midges of the genus *Culicoides*. The most severe impact of the disease on livestock consists in a congenital arthrogryposis/hydranencephaly syndrome affecting lambs, kids, and calves. The emergence of SBV at the end of 2011 in North Europe and the diffusion rate with which it has then affected Belgium, Germany, France, Italy, Luxemburg, the Netherlands, Spain, and the United Kingdom (EFSA 2012) is a reminder of the threat that the introduction of new diseases poses for European countries. Understanding the spatial patterns of vector-borne diseases can provide insight to their causes and controls.

Geographic Information Systems (GIS) and related technologies, like remote sensing, are increasingly used to analyse geographical distribution of diseases as well as relationships between pathogenic factors (causative agents, patients, vectors, and hosts) and their geographic environments. Geographic Information Systems can provide a means to meet the demands of outbreak investigation and response, where understanding the spatial spread and dynamics of an outbreak is central to the design of prevention and control strategies (Ruankaew 2005).

In the framework of the EU funded project: 'International Network for Capacity Building for the Control of Emerging Viral Vector Borne Zoonotic Diseases (Arbo-zoonet)' (2008-2011), the Istituto Zooprofilattico Sperimentale dell'Abruzzo e del Molise 'G. Caporale' (IZSAM) realised a web based database and GIS application to collect, retrieve, share and display epidemiological data and spatial distribution on WND, CCHF, RVF, and SBV useful to understand their spreading and to implement efficient early-warning and control systems.

Materials and methods

Data collection and flow

Arbo-zoonet database uses an entity-relationship model to integrate different datasets and data sources. The current version of Arbo-zoonet database focuses on 4 vector-borne diseases. The database contains the following epidemiological information (at polygon and point level): administrative location or point of outbreak occurrence, year of first occurrence, suspect and/or confirmation date, involved serotypes/subtypes, number of infected cases, number of deaths, animal species or human cases involved, diagnosis, causes or related data source, etc.

Data are stored using a hierarchical geographical level (Country, Region or Province), or, if available, by latitude and longitude coordinate using the WGS84 Spatial Reference System.

Data sources used to collect the epidemiological information are divided in:

- official data on disease outbreaks from the World Animal Health Information System (WAHIS) by World Organitation for Animal Health (OIE); the Animal Disease Notification System (ADNS) by the European Commission (EC); the National Information System's reports on human cases published by World Health Organization (WHO); the Food and Agricolture Organization of the United Nation (FAO); the European Centre for Disease Prevention and Control (ECDC), the Istituto Superiore di Sanità (ISS), the Centers for Disease Controls and Prevention (CDC);
- non official data published in scientific papers or in non-official reporting systems, like ProMed notification, Eurosurveillance, etc.

An *ad hoc* web interface and the Istituto Zooprofilattico Sperimentale dell'Abruzzo e del Molise 'G. Caporale' staff both allow for the regular update of relevant data.

Technologies

The technological stack used to build the Information System is composed by Oracle 10g Database Management System (DBMS) and ESRI ArcGIS Server 10.03. The epidemiological data are stored into the Oracle 10g database and connected to the GIS server through ESRI ArcSDE. The information is then visualized as standard ReST map services and shared by the WebGIS application.

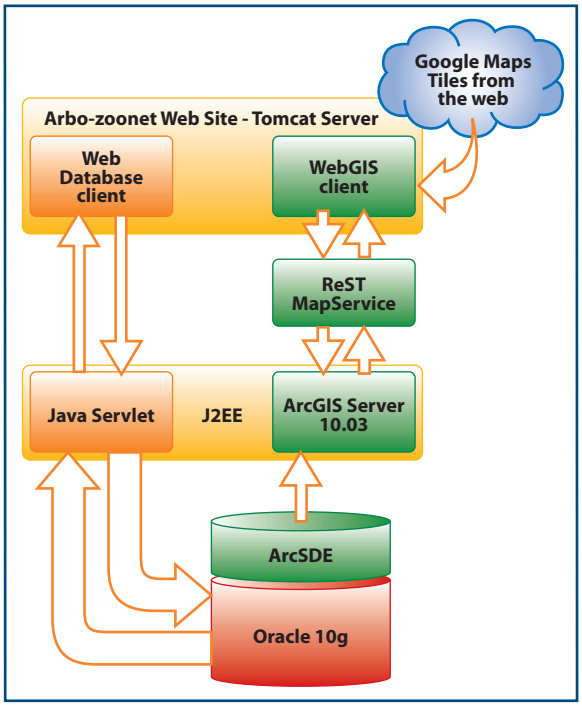

Figure 1. *The Arbo-zoonet technology scheme.*

At the database level, a group of views have been created to summarize descriptive and geographical data, which will be put at disposal of the WebGIS application developed with the ArcGIS Server Javascript extensions for the Google Maps API to facilitate and optimise the mash-up approach.

The Web Database client application works on the same dataset and provides the user with a management environment capable to perform, add, edit, and delete operations on the stored data. Such operations are driven by Java Servlets, which executes the allowed tasks for every user, taking into consideration their specific privileges.

Both the Web Database and the WebGIS client applications are deployed on an IZSAM server, running Apache Tomcat and easily accessible from the Arbo-zoonet Project homepage, using a common web browser (Figure 1).

The Web Database and WebGIS applications

The Arbo-zoonet Information System can be accessed by a user's profile regulated authentication procedure. It is composed by 2 sections:

1. Web Database application;
2. WebGIS application.

The Web Database application allows authorised users to query the epidemiological information stored in the database and manage the database content. Each registered user belongs to a specific category with a defined role, which allows for performing different activities:

- the 'Read' role permits only to view data stored into the database without the possibility to insert/delete/modify the data;
- the 'Read-Insert' role allows user to view/insert/modify data, but it does not permit to delete data;
- the 'Read-Insert-Delete' role allows for viewing/inserting/modifying/deleting all kind of data.

The main menu features 4 sections (Figure 2), available for all the users:

1. Outbreaks, which permits to search and filter the outbreaks data according to disease name, territory of interest (country/region/administrative unit), suspect or confirmation dates, year of occurred outbreak, or related data source.
2. Distributions, which allows for searching and filtering the aggregated disease information according to disease name, territory of interest

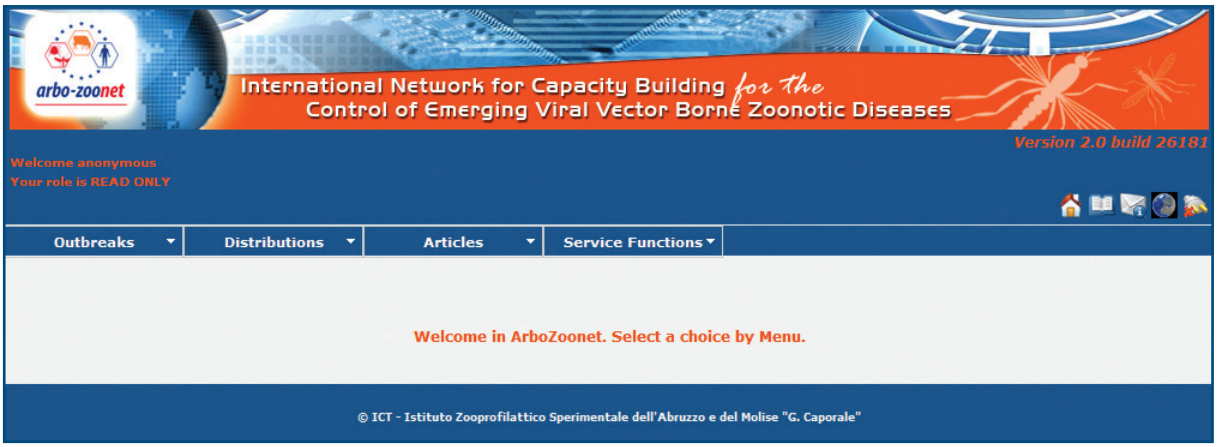

Figure 2. *The Arbo-zoonet Information System homepage and main menu.*

(country/region/administrative unit), disease period (start/end), involved serotypes, diagnosis, causes, or related data source.

3. Articles, which allows for searching and filtering data related to the articles stored into the database according to title, article type (book/journal/review etc.), abstract, authors, keywords, or the related uploaded document.
4. Service functions, which contains a sub-menu with navigation functions (homepage and logout) and the link to the user's personal data page.

Users with 'Read-Insert' and 'Read-Insert-Delete' roles can also access the 'insert' and 'delete' forms (contained in the above descripted sections) to insert/modify/delete data.

The WebGIS application is available for all the registered users by clicking on the 'Go to the map' button, placed at the right top angle of the

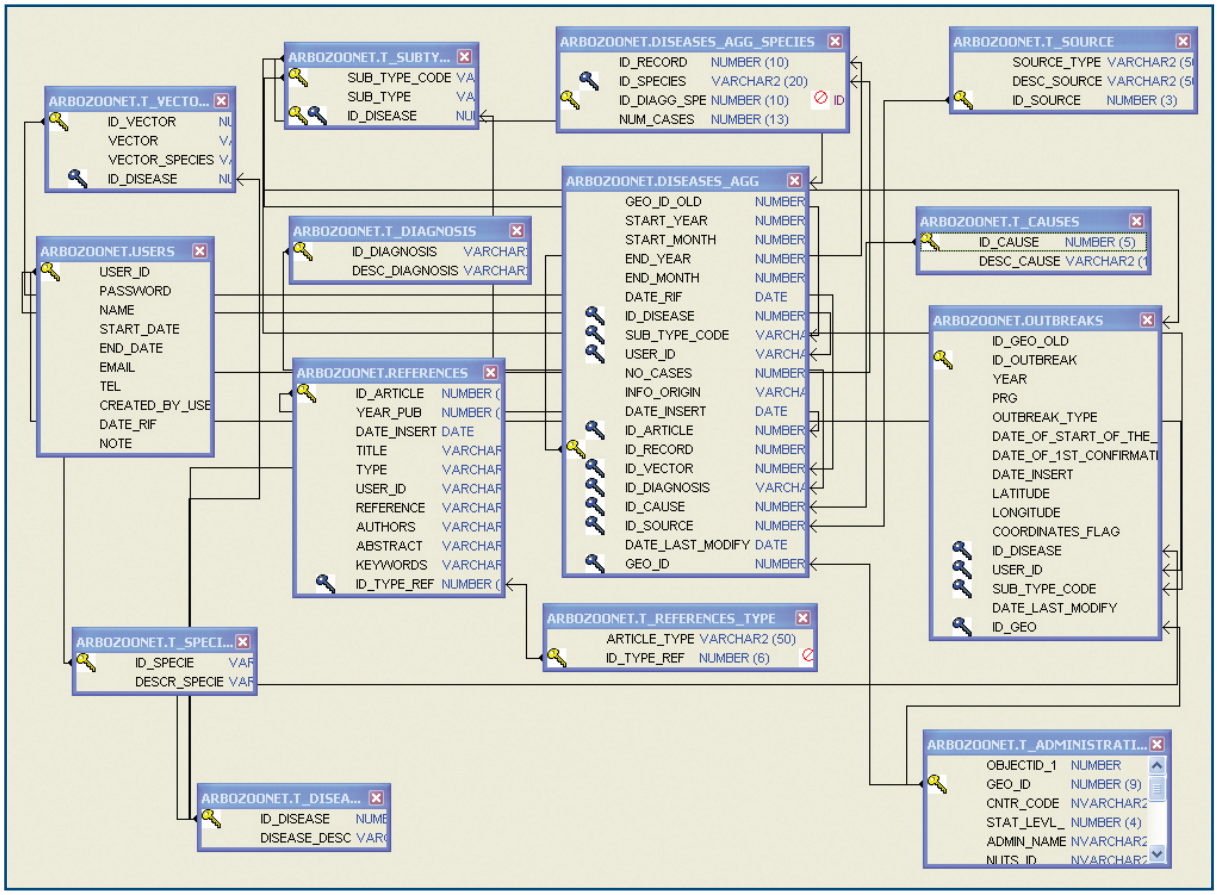

Figure 3. *Database structure and table relation and join.*

Veterinaria Italiana 2016, **52** (2), 161-168. doi: 10.12834/VetIt.522.2484.1

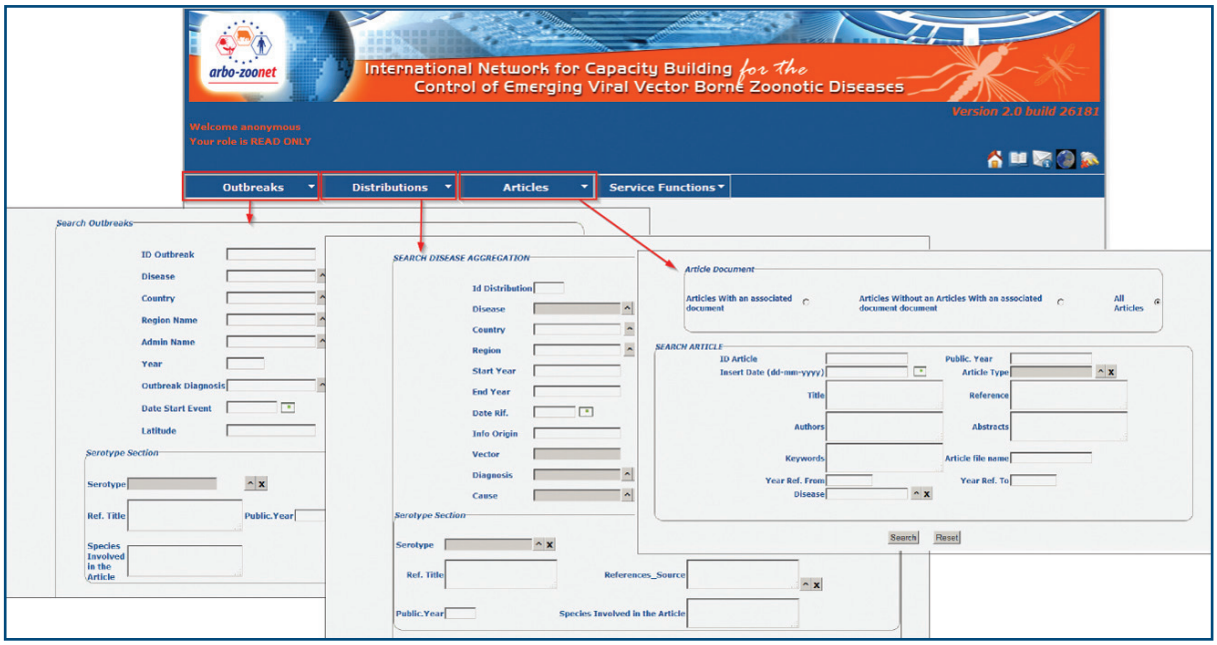

Figure 4. *The web database application modules.*

Arbo-zoonet Information System homepage. The application has been developed as a typical web 2.0 mash-up, putting together resources coming from different web-services. It mixes the high spatial resolution of the Google Maps tiled maps (Roadmap, Satellite, Hybrid, and Terrain) with the disease data provided by the IZSAM GIS server and allows the users to interact with the data exposed through the ReST map service. It permits to search the database for epidemiological information, filtered on the base of disease, host species, time interval, and data source criteria. The results are displayed both as thematic maps of disease distribution (administrative units) and outbreaks (points) and tables.

Disease distribution data are divided in 2 categories:

- autochthonous (red polygons), if the infection was originated in the same area of the distribution;
- imported (yellow polygons), if the infection was originated in a foreign area.

Outbreak data are represented as a point layer. Each point is displayed using the coordinates notified in the official systems or reported in literature. The high spatial resolution of the Google base maps makes it possible a fast (qualitative only) visual analysis to determine the environmental characteristics of the outbreaks location in terms of topography, landuse, presence of water, and vegetation.

At the bottom of the map there are 2 sortable tables showing the database records found for disease 'distribution' data (first tab) and disease 'outbreaks' data (second tab) (Figure 5). Table results are organized in 50 records per page and every column is ascending or descending sortable. Using the spatial query tool, available in the toolbar, the user can add a spatial filter to the alphanumeric filters already defined in the panel on the right. So, it could be considered as a tool to refine spatially and adjust the first query. The search by coordinates panel helps the users in the phase of bibliographic survey. The provided tools allow for locating a given set of coordinates within the boundaries of a Country, Region or Province as identified in the bibliographic source.

The 'Legend' panel contains the legend with the categories for the distributions and the outbreak layers.

Results

The structure of the database is represented in the following scheme, reporting all the tables and their relationships (Figure 3).

The web database application insert forms for disease distribution data, outbreak data, and articles are shown in Figure 4.

Table I. *Summary of the disease data stored in the database.*

Disease	Num. of disease distribution records	Num. of disease outbreak records
Crimean-Congo haemorrhagic fever	292	7
West Nile Disease	586	1382
Rift Valley fever	201	183
Schmallenberg virus	264	75

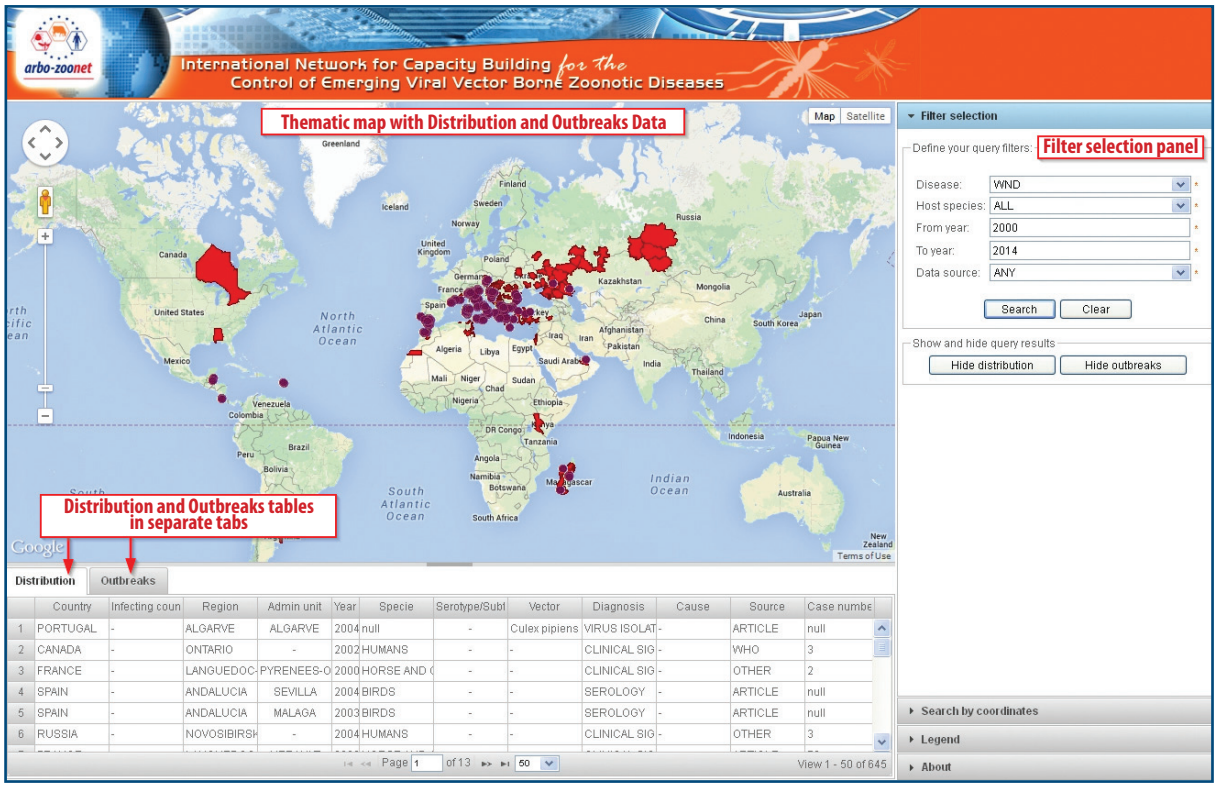

Figure 5. *Alphanumeric search results displayed as map and tables*

Disease data are recorded from 1943 for the CCHF, from 1951 for the WND, from 1976 for the RVF, and from 2011 for SBV. Table I shows the total number of records in the database both for the disease distribution and outbreaks.

The WebGIS user interface is organised in a thematic map window, a filter selection panel, and result tables (Figure 5):

The 'Search by coordinates' tool helps the users in checking coordinates and administrative units reported in literature. In the Figure 6, latitude and longitude identifies the Van province, in Turkey.

Discussion

Vector-borne zoonotic diseases are of major public concern, as large predicted environmental changes may favour their emergence or their spread in Europe. Crimean-Congo haemorrhagic fever, WND, and RVF represent an important group of infections for humans and animals, and an emerging sanitary threat in the Mediterranean Basin and in the neighbouring Countries.

The Arbo-zoonet Information System was developed within the 'International Network for Capacity Building for the Control of Emerging Viral Vector Borne Zoonotic Diseases (Arbo-zoonet)' and the final output should be data sets and methodologies to understand and model the underlying epidemiological mechanisms of these 3 diseases at any level of the chain and the impact of climate and environmental changes, as well as offering an assessment of the risk of introduction and circulation of viruses in diseases-free areas.

The principal focus of Arbo-zoonet Information System is to transfer and disseminate knowledge and technologies to develop strategies for integrated prevention and control measures of animal diseases.

The systematic collection, analysis, and interpretation of data is essential to design, implement, and evaluate interventions on public health.

The webGIS application is the best way to show and share geo-referenced information about disease distribution and outbreaks on the Internet. Basic and analytical applications of GIS in epidemiology can help in visualizing and analysing geographic distribution of diseases through time, thus revealing space-temporal trends, patterns, and relationships that would be more difficult or obscure to discover in tabular or other visualization formats.

Nowadays, webGIS application and geospatial web services are often used as decision-support systems in public and animal health.

At the international level, Internet-based computer systems such as WAHIS, developed by OIE, as well as the Global Animal Disease Information System (EMPRES-i) developed by FAO, process data on

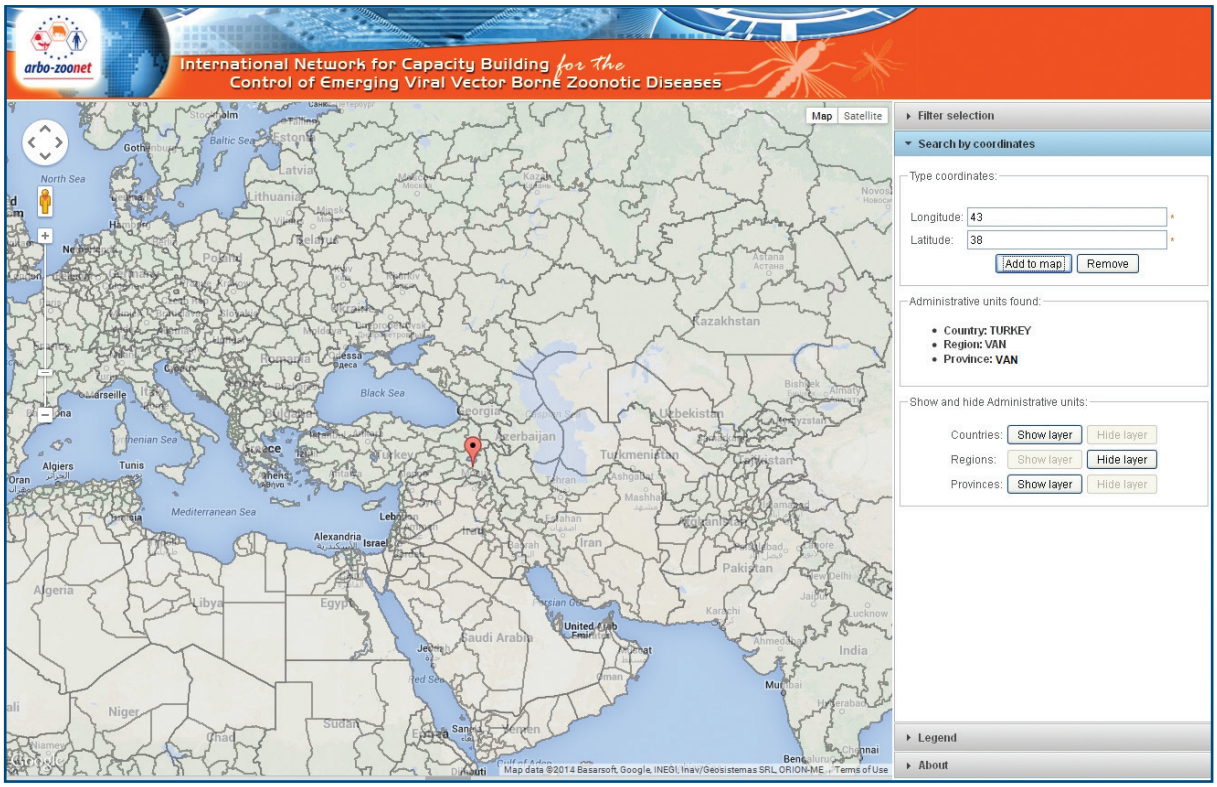

Figure 6. *Search by coordinates.*

animal diseases, making them available through dedicated web mapping application.

On the public health site, the WHO as well as the CDC, collect information on diseases in order to monitor, prevent, and suggest the most appropriate interventions in the widespread contagion and epidemics. In this regard, the CDC GIS plays an important part in health promotion and protection.

In the Abo-zoonet system official and unofficial data sources are used to collect epidemiological information on target diseases. Its database stores data both on human and animal cases, which will be useful to better understand the epidemiology of vector-borne zoonoses such as RVF, WNF, and CCHF.

The user-friendly interface and a strictly selected set of tools designed to navigate and query the spatial database facilitate the data readability and accessibility.

Maintaining and distributing high resolution base cartography requires large resources in terms of funds (collect or buy data and licenses to distribute them) and hardware/networking capabilities; using web services coming from third part providers (as Google Inc.) allowed for focusing the efforts on the real goal of the project, namely the epidemiological data sharing.

The collection of relevant epidemiological data is fundamental for any science-based assessment of the risks of pathogen introduction and/or spread in defined geographical areas. In this view the Arbo-zoonet has been used also during the SBV emergency to collect information on a new discovered vector-borne disease proving to be a flexible tool that could be used in the future also to manage data on additional diseases.

References

Ahmed J., Bouloy M., Ergonul O., Fooks A., Paweska J., Chevalier V., Drosten C., Moormann R., Tordo N., Vatan-sever Z., Calistri P., Estrada-Pena A., Mirazimi A., Unger H., Yin H. & Seitzer U. 2009. International network for capacity building for the control of emerging viral vector-borne zoonotic diseases: ARBO-ZOONET. *Euro Surveill*, **14** (12), pii=19160.

Bagnarelli P., Marinelli K., Trotta D., Monachetti A., Tavio M., Del Gobbo R., Capobianchi M.R., Menzo S., Nicoletti L., Magurano F. & Varaldo P.E. 2011. Human case of autochthonous West Nile virus lineage 2 infection in Italy, September 2011. *Euro Surveill*, **16** (43), pii=20002.

Barzon L., Pacenti M., Franchin E., Lavezzo E., Masi G., Squarzon L., Pagni S., Toppo S., Russo F., Cattai M., Cusinato R. & Palù G. 2013. Whole genome sequencing and phylogenetic analysis of West Nile virus lineage 1 and lineage 2 from human cases of infection, Italy, August 2013. *Euro Surveill*, **18** (38), pii=20591.

Calistri P., Giovannini A., Hubalek Z., Ionescu A., Monaco F., Savini G. & Lelli R. 2010. Epidemiology of West Nile in Europe and in the Mediterranean Basin. 2011. *The Open Virology Journal*, **4**, 29-37.

Chevalier V., de la Rocque S., Baldet T., Vial L. & Roger F. 2004. Epidemiological processes involved in the emergence of vector-borne diseases: West Nile fever, Rift Valley fever, Japanese encephalitis and Crimean-Congo haemorrhagic fever. *Rev Sci Tech*, **23** (2), 535-555.

European Food Safety Authority (EFSA). 2012. Schmallenberg virus: analysis of the epidemiological data and Impact assessment. *EFSA Journal*, **10** (6), 2768.

Gubler D.J. 1991. Insects in disease transmission. *In* Hunter tropical medicine (G.T. Strickland, ed). 7th ed. Philadelphia (PA), W.B. Saunders, 981-1000.

Hoffmann B., Scheuch M., Höper D., Jungblut R., Holsteg M., Schirrmeier H., Eschbaumer M., Goller K.V., Wernike K., Fischer M., Breithaupt A., Mettenleiter T.C. & Bee M. 2012. Novel orthobunyavirus in cattle, Europe. *Emerg Infect Dis*, **18** (3), 469-472.

Kortekaas J., Ergönül O. & Moormann R.J. 2010. Interventions against West Nile virus, Rift Valley fever virus, and Crimean-Congo hemorrhagic fever virus: where are we? *Vector Borne Zoonotic Dis*, **10** (7), 709-718.

Mild M., Simon M., Albert J. & Mirazimi A. 2010. Towards an understanding of the migration of Crimean-Congo hemorrhagic fever virus. *J Gen Virol*, **91** (Pt 1), 199-207.

Murgue B., Murri S., Triki H., Deubel V. & Zeller H.G. 2001. West Nile in the Mediterranean basin: 1950-2000. *Ann N Y Acad Sci*, **951**, 117-126.

Pepin M., Bouloy M., Bird B.H., Kemp A. & Paweska J. 2010. Rift Valley fever virus (Bunyaviridae: Phlebovirus): an update on pathogenesis, molecular epidemiology, vectors, diagnostics and prevention. *Vet Res*, **41**, 61.

Ruankaew N. 2005. GIS and epidemiology. *J Med Assoc Thai*, **88** (11), 1735-1738.

Sutherst R.W. 2004. Global change and human vulnerability to vector-borne diseases. *Clin Microbiol Rev*, **17**, 136-173.