Data management and analysis systems for bluetongue virus zoning in Australia

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Summary

Bluetongue virus (BTV) monitoring data in Australia is managed using a secure web-enabled centralised database. Scientists across the country submit virological and entomological data from sentinel and other sites using the Internet. Automated reporting and mapping systems make this data immediately available to all users. This system underpins the process used for defining zone boundaries. Immediate access to monitoring results allows the zones to be redefined as soon as any evidence of expansion of the area of BTV activity is detected. The method used to define zone boundaries, incorporating detailed information on vector and virus activity, property boundaries and subdivision boundaries, geography and climate, is described.

Keywords

Australia – Bluetongue virus – Free zone – Geographic information system – Information system – Internet – Mapping – Surveillance zone – Zones.

In many countries where bluetongue virus (BTV) is present, environmental and other factors influence the distribution of the virus and its vectors, resulting in free and infected areas, which can change over time. The Office International des Épizooties (OIE) has introduced the concept of zones to facilitate safe trade from those areas of a country that are free from the virus. Substantiation of zone boundaries and zone status requires effective monitoring systems to detect changes in the distribution of BTV, in response to changing climatic or environmental conditions.

Since the 1970s, Australia has monitored virus and vector distribution using a combination of sentinel animals for serosurveillance and virus isolation, and vector collections at sentinel and other sites, supplemented with cross-sectional surveys. Specimens from the field are analysed in a national network of laboratories. Novel approaches are required to rapidly collect, analyse, interpret and disseminate the large quantity of data generated by the monitoring programme from laboratories in different parts of a very large country with a wide range of environments. This paper describes the systems developed in Australia to manage BTV monitoring data, and to rapidly generate up-to-date zone maps in response to shifts in the distribution of the virus.

Data sources

Four main sources are used to provide monitoring data as follows:

1) Data on the seroconversion of animals within sentinel herds. This is supplemented with serotyping and viral isolation in key areas. There is an extensive network of sentinel sites covering all of Australia. Specimens are collected at intervals of between two weeks (intensively monitored areas with maximum variability in BTV distribution) and six months (areas with a long-term history of constant status). All animals are tested to demonstrate BTV seronegative status before being enrolled in sentinel herds.
2) Data on serological status of animals derived from periodic cross sectional surveys. These surveys involve only young animals (usually between six and 18 months) known to have been born and reared on the property of origin.
3) Vector trapping with the identification and quantification of *Culicoides* species. Vector traps are located at each sentinel herd site and numerous other strategically located sites.
4) Background textual information. The practical field expertise of scientists with many years of BTV experience is captured in the form of

quarterly reports. The aim of these reports is to document factors influencing the monitoring or distribution of BTV, which otherwise would not be captured in purely numerical data. For instance, a cyclone in the north-west of the country may destroy all vector traps, as well as temporarily removing all vectors from a region.

Data collection and management

Historically, local data management by participating laboratories was based on a variety of spreadsheet and database software. In order to minimise disruption to laboratory staff, these systems have been retained. A centralised Internet-based real-time database is used for data storage, management and analysis (1).

Data is submitted using a secure web interface, with access limited to authorised scientists to avoid data corruption. A block of local data in standardised format (e.g. from a spreadsheet) is simply copied and pasted onto the web page, and submitted to the central server. The data is parsed, checked for completeness and errors, and merged into the central database (checking for duplicates and updating previously submitted data). This system allows large volumes of detailed monitoring data to be integrated into the national database with only a few keystrokes, as well as allowing laboratory staff to update any previously submitted data based on subsequent tests. The core data held by the database includes the following:

Virology

- Date of sampling
- Location of sampling
- Number of animals sampled
- Number of animals at risk of seroconversion (i.e. negative prior to the sampling period)
- Number of animals seroconverted (i.e. previously negative and now positive)

Entomology

- Date of trapping
- Location of trapping

Species identified

- Number of *Culicoides* of that species identified.

The website also provides a range of data management and reporting options, including:

- Creation of new monitoring site records, identified by geographic coordinates
- Export of raw data to spreadsheet format for download and analysis
- Summary analysis of viral or vector activity at monitoring sites
- Records of data submissions by laboratory to monitor programme participation.

As analysis is based on the on-line database, all reports immediately reflect the most recently available data.

A web-enabled geographic information system (GIS) provides real-time automated mapping of the monitoring data, and allows users to view sentinel herd or vector trapping results along with the current BTV zone boundaries, roads, railways, towns, rivers etc (Fig. 1). In addition, several levels of administrative boundaries are available, including individual property boundaries. Users can zoom in to determine if a specified property is inside or outside a zoning boundary, to an accuracy of about 5 m (Fig. 2). This system displays the location of monitoring sites and uses colour coding to indicate if positive results have been observed (either seroconversions or vector species detected). The maps also allow interactive querying, so that the full monitoring details and history of a particular site can be accessed by clicking on that site (Fig. 3). This system provides immediate, up-to-date visual assessment of BTV activity in relation to the current zone boundaries, as well as giving access to the underlying data. It is used extensively to facilitate communication between programme scientists around the country during live telephone conferences. It is also used as a mechanism to communicate proposed changes to zone boundaries for approval by local experts.

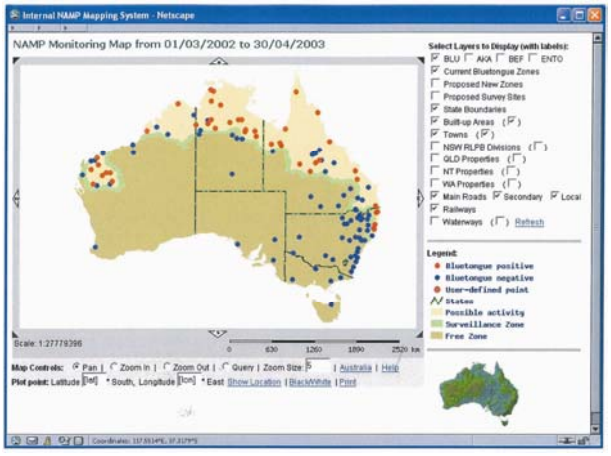

Figure 1
Interactive real-time bluetongue virus monitoring map interface, showing zoning boundaries (at the time of writing) and sentinel herd monitoring results

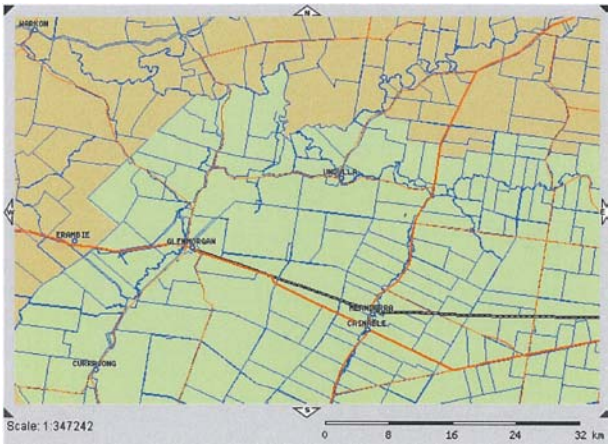

Figure 2
Detail of map in Figure 1 zoomed in to show the boundary between the free zone and the surveillance zone in south-eastern Queensland
Blue lines indicate individual property boundaries

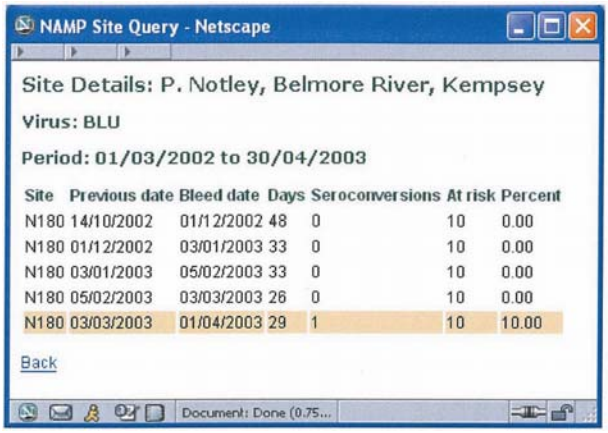

Figure 3
Clicking on a point on the map produces a pop-up window showing the full monitoring results from the specified site

Zoning

Zone boundaries are determined on the basis of monitoring results, geographical and environmental factors, and the outputs of a temporo-spatial model of vector and virus distribution (2). Three zones are defined: the free zone, the surveillance zone and the zone of possible transmission. Boundaries are determined such that the boundary between the zone of possible transmission and the surveillance zone is at least 50 km from the nearest identified BTV activity and makes biological sense. The surveillance zone is at least a further 50 km wide, providing a separation of at least 100 km between the free zone and any area of known activity. Where possible, zone boundaries follow clearly defined administrative subdivisions or property boundaries. An entire property must lie within the free zone in order to be classified as part of that zone. In some cases, the boundaries follow geographical barriers to vector spread, such as mountain ranges. Using desktop GIS tools, it is usually possible to define new zone boundaries and update them on the website in less than a day. This process is illustrated in Figures 4 to 7. An automated email distribution list is employed to inform registered users of zone updates.

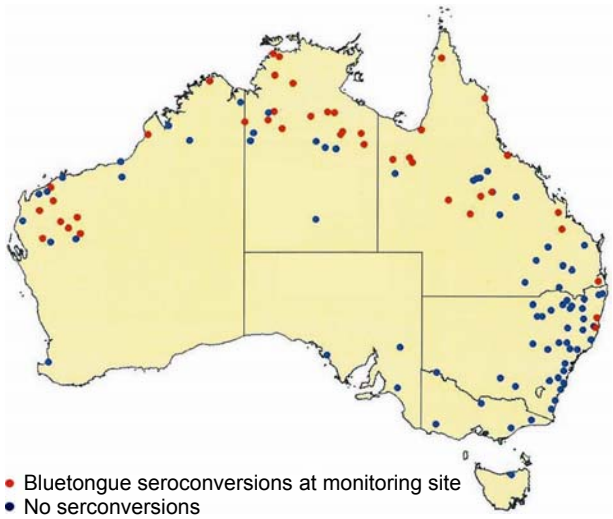

Figure 4
Step 1 of the zone boundary definition
A live link is established to the central database and monitoring site results mapped as points

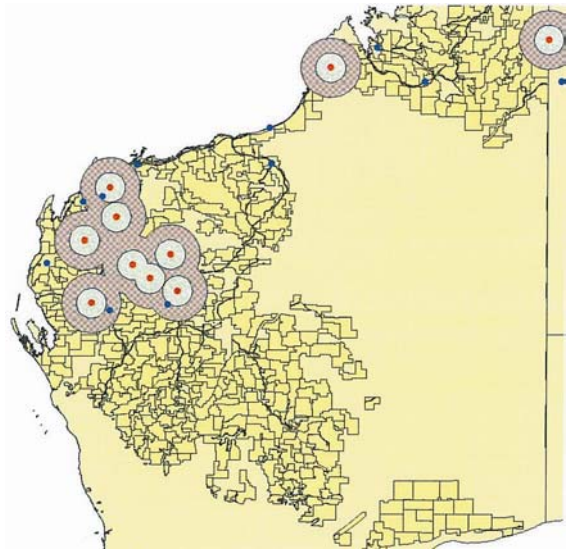

Figure 5
Step 2 of the zone boundary definition
Buffers are drawn around each positive site at distances of 50 km (minimum distance to surveillance zone) and 100 km (minimum distance to free zone)

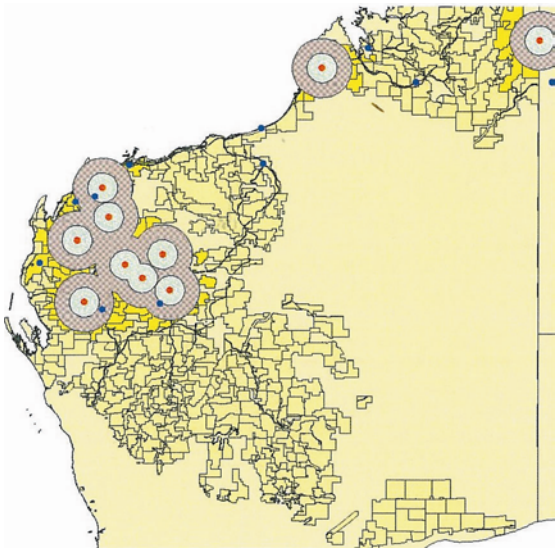

Figure 6
Step 3 of the zone boundary definition
Properties and administrative subdivisions intersecting the buffers are identified

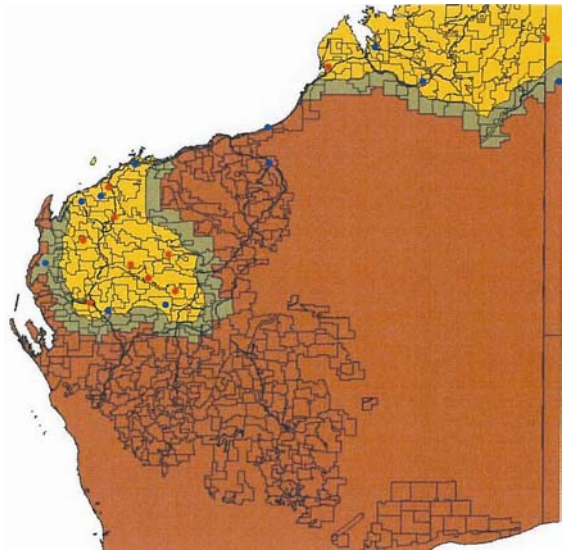

Figure 7
Step 4 of the zone boundary definition
Zone boundaries defined to enclose all selected properties, taking into account geographical features, model outputs and climatic information

The protocols governing changes to zoning boundaries are clearly defined. Any evidence of BTV activity within less than 100 km of the current free zone requires immediate re-drafting of the zone boundaries. Decreases in the distribution of BTV resulting in demonstrable lack of activity in an area for at least two years also result in changes to zone boundaries to expand the free zone. These reviews occur after a meeting of experts who consider all the monitoring results and other relevant factors.

The system described demonstrates how advanced information management tools can be used to maximise the effectiveness of a BTV monitoring programme. The system supports the definition of timely and accurate zone boundaries, providing a high degree of confidence as well as providing a strong scientific basis to negotiation of health protocols to support trade. The current Australian BTV zones are displayed at www.namp.com.au.

Acknowledgements

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