Bluetongue surveillance in the Campania Region of Italy using a geographic information system to create risk maps

V. Caligiuri[(1)], G.A. Giuliano[(1)], V. Vitale[(1)], L. Chiavacci[(2)], S. Travaglio[(2)], L. Manelli[(3)], S. Piscedda[(3)], M. Giardina[(3)] & R. Mainolfi[(3)]

(1) Osservatorio Epidemiologico Veterinario Regione Campania, Istituto Zooprofilattico Sperimentale del Mezzogiorno, Via Salute 2, 80055 Portici, Italy
(2) Istituto Zooprofilattico Sperimentale del Piemonte, Liguria e Valle D'Aosta, Via Bologna, 10154 Torino, Italy
(3) Formez, via Campi Flegrei 34, Arco Felice, 80072 Pozzuoli, Italy

Summary

The aim of the project was the implementation of a geographic information system (GIS) to study areas of the Campania Region that are potentially at risk for bluetongue (BT) infection. As a first step, environmental, meteorological and climatic features were surveyed to evaluate areas where *Culicoides* could be present. A risk map was developed and five zones with different risk levels were defined. Data from *Culicoides* trapping were surveyed to evaluate the capability of the risk map to predict presence/absence of vectors. Finally, data from 2002 BT surveillance (outbreaks and serologically positive sentinels [SPS]) were compared to the map. Captures of *Culicoides*, SPS and BT in areas the map indicated as a medium/high risk level, seem to confirm reliability of the produced map. However, very few *C. imicola* were captured in these medium/high risk areas.

Keywords

Bluetongue – Campania – *Culicoides* – Geographic information system – Italy – Mapping – Regression – Remote sensing – Surveillance – Vector-borne disease.

Introduction

Bluetongue (BT) is an infectious disease of ruminants caused by bluetongue virus (BTV) transmitted by biting midges of the genus *Culicoides* of which *C. imicola* has been implicated as the major vector in the Mediterranean Basin. The first outbreak of BT in Italy was reported in Sardinia in 2000 and in the same year many other regions of southern Italy were affected by the disease (8). Areas in which *C. imicola* are found are considered at risk to BT but usually the vector is not identified until after outbreaks of the disease have occurred. Determining *Culicoides* distribution before the disease outbreaks occur could be useful to target control measures, such as vaccination, use of insecticide and housing of susceptible animals in periods of peak vector activity (13).

The goal of this study was to implement a geographic information system (GIS) to define a risk map (12) for the presence/absence of *Culicoides*. Climatic and environmental factors primarily govern the distribution of the vector, but soil type may also influence the establishment of *C. imicola* in any given zone (9). *C. imicola* persists in areas where the average daily maximum temperature exceeds 12.5°C, requiring wet, organically enriched soil or mud and an optimal annual rainfall of 300-700 mm. Other factors, such as irrigation and standing water near water troughs, may influence humidity and promote breeding with areas in the vicinity of animal holdings being the most suitable. The vector can fly for distances of a few hundred metres, but warm-humid winds can transport them for distances of greater than 7 km and to altitudes of 500-2 000 m (6).

Methods

Two LandSat 7 (30 mt pixels) remote sensing images of the Campania Region were prepared in 2000, georeferenced in UTM ED50 with Erdas Imagine 8.4 software (Fig. 1). Using LandSat images with the minimum distance algorithm, the land use was determined and listed under the following

classes: evergreen and deciduous trees, grazing ground, water, uncultivated areas, cultivated areas, urban areas, hazelnut areas, burnt areas, pits and sand. The land use was then further classified to identify the areas where livestock occur (3, 10).

Figure 1
LandSat 7 image georeferenced in UTM ED50

From a digital elevation model (DEM) using ArcGis 8.1 software (especially with spatial analyst extension), the following maps were obtained: slope, elevation, aspect and stream network. The maps were reclassified giving the areas significance according to the predicted habitat of *Culicoides* species. Using meteorological data from 30 weather stations (points on the map with a meteorological value) and performing statistical interpolations, a temperature chart was obtained using the regression method between height and temperature (the correlation value was: –0.0034). The humidity and precipitation chart was drawn using the inverse distance weighted (IDW) interpolator to create a grid map with a value for any point on the map (11). All the maps were combined to obtain an initial result. Data on insect captures refer to the monthly average number of *Culicoides* collected in fixed traps according to the national entomological surveillance plan in Italy.

The choice of area for the positioning of traps was made both on the basis of previous capture results and on the areas predicted to have a greater number of domestic ruminants. One fixed trap was positioned every 1 600 km², which is equal to four cells of the grid into which the territory of the Campania Region was subdivided under the BT surveillance plan. Each cell presented a square of 20 km². The traps were located on farms chosen by the veterinary services according to the presence of cattle and dependent on the agreement of the owner. The capture of insects was performed once a week between sunset and sunrise and the trapped insects were sent to the reference centre in Teramo to be counted and identified (1). Both the quantity of *Culicoides* as well as the presence of *Culicoides imicola* were taken into consideration. The information on capture covers the period from February 2001 to November 2002.

Results

Based on biological characteristics of *C. imicola*, the most suitable habitat was defined and a soil map was produced (Fig. 2); information by satellite imaging and possible animal presence (depending on territorial characteristics) were combined and five risk classes were identified, from low probability (score 0) to one of very high probability (score 4) for the presence of *C. imicola*.

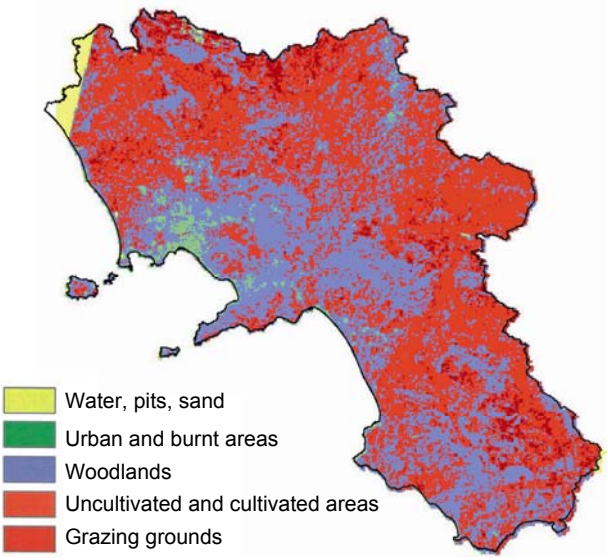

Figure 2
Land use reclassification based on the presence of *Culicoides* probability

The presence of clay soil may also influence the presence and breeding of *C. imicola*. Therefore, based on DEM, a map was produced emphasising moisture-retentive zones (Fig. 3) where breeding by *C. imicola* is most likely to occur. This map also takes into account slope, elevation and aspect.

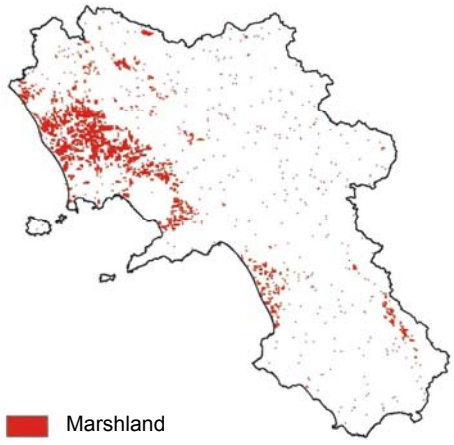

Figure 3
Zones in which swamps can develop

Temperature, rainfall and humidity maps were also produced (Figs 4, 5 and 6). The mean maximum temperature in the Campania Region is over 12.5°C for many consecutive months, so only mean minimum temperatures for the winter months (November to March) were used.

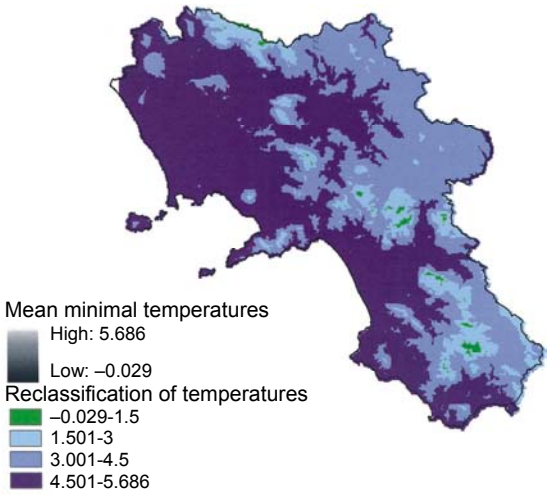

Figure 4
Mean minimal temperatures in the winter months

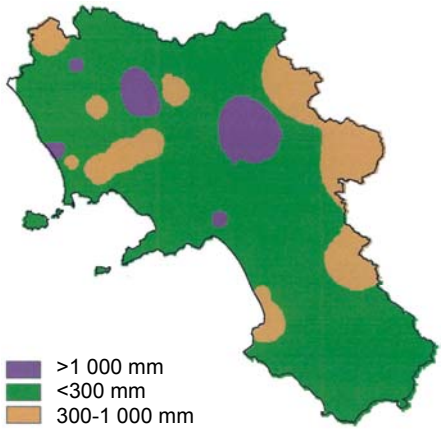

Figure 5
Rain table

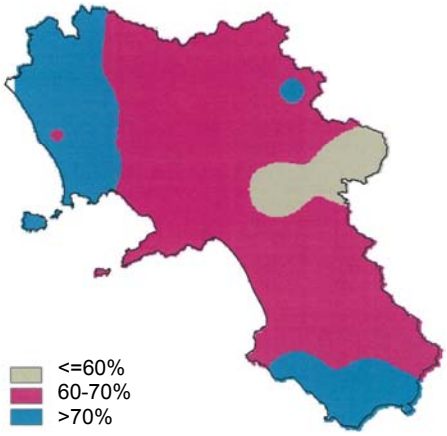

Figure 6
Medium value of humidity in recent years

Climatic and territorial classifications were combined to map the probability of presence/absence of *C. imicola* (Figs 7 and 8) with probability of presence of *Culicoides* subdivided amongst five risk levels (low, medium-low, medium, medium-high and high). Results from fixed traps in medium and medium-high risk areas were mapped (Fig. 8 and Table I).

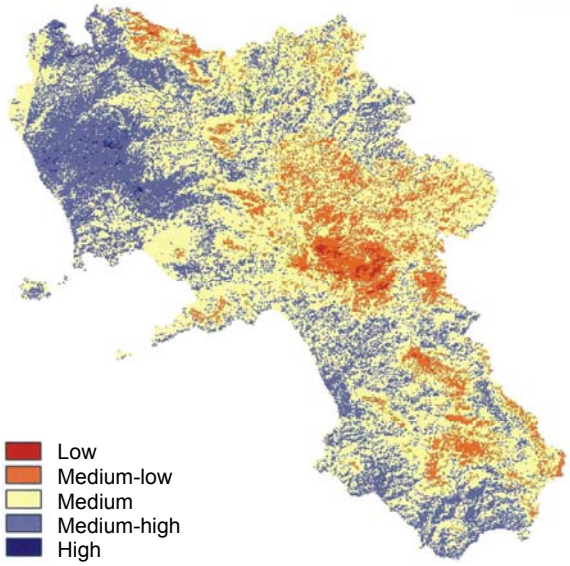

Figure 7
Map of risk level

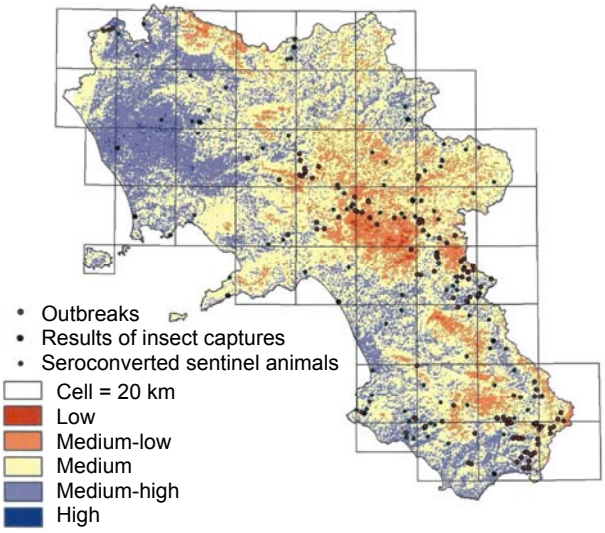

Figure 8
Map of risk level based on insect capture results, bluetongue outbreaks and bluetongue seroconverted sentinel animals

Culicoides were captured in all of the traps, but *C. imicola* was identified at only three trap sites (Table II). Serologically positive sentinels (SPS) and BT outbreaks were also included in the risk map (Fig. 8). SPS were distributed throughout the region but more occurred in the south. Unfortunately, only 139 outbreaks of 251 were georeferenced and

mapped; all emanated from the south/south-eastern part of the region. Outbreaks and positive sentinels were found mostly in the medium or high-risk level zones (Tables III and IV). About 10% of the outbreaks, and 12% of the positive sentinels, occurred in medium-low risk level areas, while 90% and 88%, respectively, occurred in medium-high or high-risk level areas (Fig. 8).

Table I
Number of *Culicoides* trapped according to predicted risk levels

Risk level	Count	Percentage
1 Low	0	0
2 Medium-low	0	0
3 Medium	6	55
4 Medium-high	5	45
5 High	0	0
Total	11	100

Table II
Insect collections, 2002

Trap ID	No. of collections 2002	No. of collections (May-October)	Mean no. of *Culicoides* (May-October)	No. of collections positive for *C. imicola* (November)
0	32	23	66	
1	3	3	99	
2	28	26	107	
3	33	26	237	1
4	14	14	3	
5	33	21	119	2
6	49	21	190	13
7	12	12	9 612	
8	2	2	52	
9	25	23	643	
10	13	10	27	

Table III
Positive sentinels by risk area

Risk level	Count	Percentage
1 Low	0	0
2 Medium-low	11	12
3 Medium	54	60
4 Medium-high	24	27
5 High	1	1
Total	90	100

Table IV
Bluetongue outbreaks segregated by risk level, November 2001-November 2002

Risk level	Count	Percentage
1 Low	0	0
2 Medium-low	15	11
3 Medium	86	62
4 Medium-high	38	27
5 High	0	0
Total	139	100

Livestock distribution, positive sentinels and BT outbreaks are presented in Figure 9.

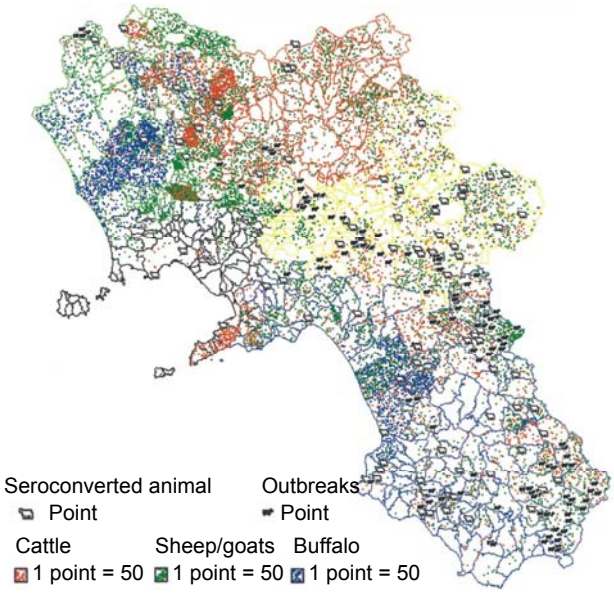

Figure 9
Livestock distribution and identification of seroconverted livestock and bluetongue outbreaks

Discussion

The risk map identified 90% of the Campania Region to be in the medium-high risk zone for presence of *C. imicola*. Data from traps seem not to confirm the reliability in predicting the presence of *C. imicola*. However, positive captures of *Culicoides* in all 11 fixed traps, and finding SPS and BT infection in predicted medium/high-risk areas, suggests reliability of the model (2). Other *Culicoides* species could be involved in transmission of the disease and this observation has been supported by other studies (5, 7). Moreover, it is possible that the capture methodology needs to be improved (more captures and more traps) to identify low levels of *C. imicola* (4). The distribution of susceptible animal populations, which was not included, could possibly

improve this model. Unfortunately, georeferenced farms are not yet available.

Analogous methodology should be applied in other regions with different territorial and climatic characteristics to verify the capability of the model to predict the presence or absence of *Culicoides* species.

If the role of other *Culicoides* species in BTV transmission should be confirmed, the model could be tested in that context.

References

1. Anon. (2001). – Sistema nazionale di sorveglianza della febbre catarrale degli ovini (Bluetongue) – piano di sorveglianza entomologica 2001. Allegato I, Parte II, Rev. 2-23.10.01, 1-12.
2. Baylis M., Mellor P.S., Wittmann E.J. & Rogers D.J. (2001). – Prediction of areas around the Mediterranean at risk of bluetongue by modelling the distribution of its vector using satellite imaging. *Vet. Rec.*, **149**, 639-643.
3. Burrough P.A. (1986). – Principles of geographical information system for land resources assessment. Clarendon Press, Oxford, Monograph No. 12.
4. 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**, 132-138.
5. Caracappa S., Torina A., Guercio A., Vitale F., Calabro A., Purpari G., Ferrantelli V., Vitale M. & Mellors P.S. (2003). – Identification of a novel bluetongue vector species of *Culicoides* in Sicily. *Vet. Rec.*, **153** (3), 71-74.
6. De Liberato C., Purse B.V., Goffredo M., Scholl F. & Scaramozzino P. (2003). – Geographical and seasonal distribution of the bluetongue virus vector, *Culicoides imicola*, in central Italy. *Med. Vet. Entomol.*, **17** (4), 388-394.
7. Gerry A.C., Mullens B.A., MacLachlan N.J. & Mecham J. (2001). – *Culicoides sonorensis*, vectorial capacity, bluetongue virus, infection rate, cattle. *J. Med. Entomol.*, **38**, 197-209.
8. Goffredo M., Conte A., Cocciolito R. & Meiswinkel R. (2003). – Distribuzione e abbondanza di *Culicoides imicola* in Italia. *Vet. Ital.*, **47**, 22-32.
9. Koslowsky S., Staubach Ch., Kramer M. & Wieler L.H. (2003). – Bluetongue disease in Deutschland? Risikoabschätzung mit Hilfe eines geographischen Informationssystems (GIS). *In* Bericht des 25 Kongresses der Deutschen Veterinärmedizinischen Gesellschaft e.V.: Schwerpunktthema 'Zoonosen', 3.4.-4.4.2003, Berlin, 341-346.
10. Piscedda S. (1999). – Introduzione ai Sistemi Informativi Geografici, Quaderni del Progetto Panda, Ministero delle Politiche Agricole e Forestali, 5-46.
11. Tomlin D. (1990). – Geographic information systems and cartographic modeling. Prentice-Hall, Englewood Cliffs, New Jersey, 96-99.
12. Ward M.P. & Carpenter T.E. (2000). – Techniques for analysis of disease clustering in space and in time in veterinary epidemiology. *Rev. Prev. Vet. Med.*, **45**, 257-284.
13. Wittmann E.J., Mellor P.S. & Baylis M. (2001). – Using climate data to map the potential distribution of *Culicoides imicola* (Diptera: Ceratopogonidae) in Europe. *Rev. Sci. Tech. Off. Int. Epiz.*, **20** (3), 731-740.