

Battling Bluetongue and Schmallenberg virus

Local scale behavior of transmitting vectors

Stockmarr, Anders; Kirkeby, Carsten; Bødker, Rene

Publication date: 2015

Link back to DTU Orbit

Citation (APA): Stockmarr, A. (Author), Kirkeby, C. (Author), & Bødker, R. (Author). (2015). Battling Bluetongue and Schmallenberg virus: Local scale behavior of transmitting vectors. Sound/Visual production (digital)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.

- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Battling Bluetongue and Schmallenberg virus: Local scale behavior of transmitting vectors

Anders Stockmarr¹, Carsten Kirkeby² and Rene Bødker²

¹: Dept. of Applied Mathematics and Computer Science, Technical University of Denmark, DK-2800 Lyngby, Denmark.

 $f(x + \Delta x) = \sum_{i=1}^{\infty} \frac{(\Delta x)}{i!}$

²: National Veterinary Institute, Technical University of Denmark, DK-1870 Frederiksberg, Denmark.

Infectious Diseases, London August 10, 2015

Department of Applied Mathematics and Computer Science



Bluetongue and Schallenberg

- viral diseases that affects ruminants;
- mainly sheep, cattle and goats.







Epidemiology

- 2006: BTV-8 reaches Northern Europe.
- 2007: First case in Denmark.
- 2012: Schallenberg virus reaches Northern Europe (and Denmark).



Routes of introduction of different BTV serotypes and individual virus strains. From Wikipedia.

3 Dept. of Applied Mathematics and Computer Science, Technical University of Denmark

Epidemiology

• Vector borne: Transmitted by biting midges: Culicoides.



- Vector species:
 - Culicoides imicola (Southern Europe);
 - Culicoides schultzei (Africa, Asia, Australia and Southern Europe).
- Progression northwards first ascribed to climate changes, but it has been realized that new vectors, *Culicoides pulicaris* and *Culicoides obsoletus*, can acquire and transmit the viruses.

Bluetongue and Schallenberg diseases – Impact



 Very costly for the industry and society: A Bluetongue outbreak such as the Belgium outbreak in 2006-7 has been estimated to cost £485 million and 10.000 jobs, should a similar outbreak occur in the UK (Webb 2008).



Bluetongue outbreaks in the EU 2008-2009 (European Commission 2009)

5 Dept. of Applied Mathematics and Computer Science, Battling Bluetongue and Schmallenberg virus 10/08/2015 Technical University of Denmark

Containing the diseases



- No efficient treatment.
- Containing the diseases:
- Quarantine;
- Inoculation with live virus; BTV-8 vaccines are available now but the immunization period is not clear;

- Containing the vector.

Containing Bluetongue locally in the presence of host animals



• Placement of 50 light traps;

- Running all light traps 4 nights pr. week;
- Emptying light traps and conserving *Culicoides* for later analysis;
- Placement of host animals during nights;



Battery operated CDC UV trap

7 Dept. of Applied Mathematics and Computer Science, Technical University of Denmark





Forest! -----

Battling Bluetongue and Schmallenberg virus

10/08/2015

Host animals in upper part of field



8 Dept. of Applied Mathematics and Computer Science, Technical University of Denmark Battling Bluetongue and Schmallenberg virus 10/08/2015

Data – covariates

- Which variables means something for where the vector is?
- Breeding sites
- Distance to sheep
- Humidity
- Precipitation
- Sheep transect
- Temperature
- Wind speed

- A-D: Breeding sites
- E: 260 Sheeps kept here at night
- Sheep transect
 with 1 sheep in a
 3x3 m enclosure on
 3 catch nights
- Wind breaks: wind speed $\times \sum_{i=1}^{4} |sin(\theta_i)| 1_{\{\theta \in (0;\pi)\}}/d_i$
- Sheep scent: wind speed $\times |sin(\theta)| \mathbb{1}_{\{\theta \in (0;\pi)\}}/d$





⁹ Dept. of Applied Mathematics and Computer Science, Battling Bluetongue and Schmallenberg virus 10/08/2015 Technical University of Denmark

Data



- Female *Culicoides obsoletus* and *Culicoides pulicaris* were counted in each light trap each day;
- Problem: For 8 catch nights, due to time constraints, only 50% of the trap catches were counted (checkerboard pattern).
- All:

16 catch nights,530 trap catches,15166 female *Culicoides pulicaris* caught;4488 female *Culicoides obsoletus* caught.



Original analysis

 Analysed with a lattice model (conditional independence model), through successive conditioning. Solves problem with missing values.

Major problem

The many missing values makes it difficult to interpret dependencies, and hard to model dependencies across the spatio-temporal domain.

Details: Kirkeby et al. (2013).





Spatial and temporal correlation

- Standard regression methods do not apply, because the data points are <u>NOT stochastically independent</u>: They are <u>correlated</u>.
- Spatially: A high catch in one trap likely means many midges in the area, and thus an increased chance that neighboring traps will catch many midges as well. The further away in distance, the lesser the effect.



 Temporal: A high catch in one trap likely means many midges in the area. They may also be there tomorrow, and may have been there yesterday. The further away in time, the lesser the effect.

Standard regression methods of estimation can't handle varying correlation.

Re - analysis

- Specify the covariance structure directly:
- Spatial dependence that accounts for clustering in space;

• Temporal dependence that account for clustering in time;

• Spatio-temporal dependence that combines the two.









Re - analysis

• Specify reference points $x_0 = (x_{01}, x_{02})$ and T_0 in space and time.

 $X_{i,j,k}$ is catch at **horisontal distance** i, **vertical distance** j, **temporal distance** kfrom the reference points.

 $\mathbb{Y}_{i,j,k} = \log(\mathbb{X}_{i,j,k} + 1).$

Then the correlation between any $\mathbb{Y}_{i,j,k}$ and $\mathbb{Y}_{r,s,t}$ is modeled as

$$cor(\mathbb{Y}_{i,j,k}, \mathbb{Y}_{r,s,t}) = \rho^{\left\|\binom{i}{j} - \binom{r}{s}\right\|} \times \eta^{|k-t|}$$

14 Dept. of Applied Mathematics and Computer Science, Ba Technical University of Denmark

DTU

Re - analysis

Take $\Sigma(\rho,\eta)$ as the matrix

$$\Sigma(\rho,\eta)_{(i,j,k),(r,s,t)} = cor(\mathbb{Y}_{i,j,k},\mathbb{Y}_{r,s,t})$$

And model $\mathbb{Y} = (\mathbb{Y}_{i,j,k})$ with a multivariate normal model,

 $Y \sim N(X\beta, \sigma^2\Sigma(\rho, \eta))$

Where

- -X is the design matrix constructed from covariates,
- β is the vector of effect parameters,
- σ^2 is the residual variance.



Re - analysis

Log-likelihood:

$$\ell(\beta,\sigma^{2},\rho,\eta) = -n * \log(\sigma^{2}) - \log\left(det(\Sigma(\rho,\eta))\right) - \sigma^{-2}(\mathbb{Y} - X\beta)^{T}\Sigma(\rho,\eta)^{-1}(\mathbb{Y} - X\beta)$$

Maximized using Template Model Builder (Kristensen, to appear).

https://github.com/kaskr/adcomp

Results

| ΠΤΠ | |
|-----|--|
| DIU | |
| | |
| | |

| Covariate | Estimate (SD), obsoletus | Significance obsoletus | Estimate (SD), pulicaris | Significance pulicaris |
|--------------------------------|-----------------------------|---------------------------|--------------------------------|---------------------------|
| Intercept | -354.4(17.9) | - | -384.7(9.7) | - |
| Distance to sheep | -4.80e-3(5.05e-4) | * * * | -4.05e-3(4.25e-4) | * * * |
| Squared distance to sheep | 6.59e-2(6.92e-3) | * * * | 6.42e-2(5.93e-3) | * * * |
| Precipitation | -68.0(3.4) | * * * | -73.2(1.69) | * * * |
| Turbulence | -190.8(10.8) | * * * | -206.2(5.2) | * * * |
| Humidity | 1.07(0.05) | * * * | 1.19(0.03) | * * * |
| Temperature | 40.6(2.1) | * * * | 43.7(1.1) | * * * |
| Squared temperature | -1.3(0.07) | * * * | -1.39(0.03) | * * * |
| Wind speed | 1.84(0.2) | * * * | 2.24(0.12) | * * * |
| Squared wind speed | -0.18(0.03) | * * * | -0.23(0.02) | * * * |
| Sheep transect | - | NS | 0.44(0.10) | * |
| Breeding sites | - | NS | - | NS |
| Windbreaks | -0.12(0.05) | * | - | NS |
| Sheep scent | - | NS | - | NS |
| Windbreaks: Sheep scent | - | NS | - | NS |
| Sheep Scent: Distance to sheep | - | NS | - | NS |

(Catch night dummies left out)

17 Dept. of Applied Mathematics and Computer Science, Technical University of Denmark Battling Bluetongue and Schmallenberg virus 10/08/2015



Results: Correlations and variances

| | Estimate obsoletus | Significance obsoletus | Estimate pulicaris | Significance pulicaris |
|--------------------------------|-----------------------|---------------------------|-----------------------|---------------------------|
| Spatial correlation (100m's) | 0.79 | * * * | 0.24 | * * * |
| Temporal correlation (days) | 0.59 | * * | - | NS |
| Residual variance | 0.28 | - | 0.21 | - |

Original analysis

| | Estimate obsoletus | Significance obsoletus | Estimate pulicaris | Significance pulicaris |
|--------------------------------|-----------------------|---------------------------|-----------------------|---------------------------|
| Spatial correlation (100m's) | 0.17 | * * * | 0.06 | * * * |
| Temporal correlation (days) | - | NS | - | NS |
| Residual variance | 0.69 | - | 0.65 | - |

18 Dept. of Applied Mathematics and Computer Science, Technical University of Denmark Battling Bluetongue and Schmallenberg virus 10/08/2015



Spatio and temporal correlations



- The heavy *obsoletus* spatial correlation may suggest external sources of midges.
- The *pulicaris* spatial correlation may be ascribed to swarming.

19 Dept. of Applied Mathematics and Computer Science, Battling Bluetongue and Schmallenberg virus 10/08/2015 Technical University of Denmark

Effects



- Breeding sites;
- Windbreaks;
- Sheep scent;

20

- Sheep transect;
- Specified interaction effects.

Dept. of Applied Mathematics and Computer Science, Technical University of Denmark 10/08/2015

Nonlinear covariate effects



Effects of distance to sheep, temperature and wind speed.



Battling Bluetongue and Schmallenberg virus 10/08/2015



Conclusions

- Critical conditions: Humid, 14°-17° Celsius, and moderate wind.
- Non-critical conditions: Rainy, turbulent or no wind.
- Effects seems to be species independent.
- Special concern should be taken locally under critical conditions.
- The direct specification of correlations reveals much higher spatiotemporal correlations and reduces model error by a factor 2-3 on the logscale.

Thank you for your attention



23 Dept. of Applied Mathematics and Computer Science, Technical University of Denmark Battling Bluetorigue una commandiación y mais