GAM for modelling the prevalence of infectious diseases

Stefan Widgren^{1,2}

(1) Department of Disease Control and Epidemiology National Veterinary Institute Uppsala, Sweden (2) Department of Clinical Sciences Swedish University of Agricultural Sciences Uppsala, Sweden

GAM Workshop 23 August 2016 SLU

Introduction



Preventive Veterinary Medicine

Volume 121, Issues 3–4, 1 October 2015, Pages 343–352



Longitudinal observational study over 38 months of verotoxigenic *Escherichia coli* O157:H7 status in 126 cattle herds

Stefan Widgren^{a,} ▲· ➡, Robert Söderlund^a, Erik Eriksson^a, Charlotta Fasth^a, Anna Aspan^a, Ulf Emanuelson^b, Stefan Alenius^b, Ann Lindberg^a

Widgren et al. Vet Res (2016) 47:81 DOI 10.1186/s13567-016-0366-5



RESEARCH ARTICLE

Open Access



Data-driven network modelling of disease transmission using complete population movement data: spread of VTEC O157 in Swedish cattle

Stefan Widgren^{1,2*}^(D), Stefan Engblom³, Pavol Bauer³, Jenny Frössling^{2,4}, Ulf Emanuelson¹ and Ann Lindberg²

Environmental sampling





Study regions



Time series: Suckler herds



Time series: Dairy herds

27 -	A A	▲ ▲○ ▲	A 0 0	0 0 0	0 0	0 0	0 0 0	-11
26 -	0000		0 0 0 0	0 0 0	0 0	0 0	• • •	-11
25 -	0 0 0	0 0 0	0 0 0	0 0 0	• •	• •	• • •	
23 -		• • •			0 0	0 0	<u> </u>	8
20 -	0 0 0	• • •	A A 0	• • •	0 0	0 0	0 0 0	- <u>F</u>
19 -	• • •	0 0 0	0 0 0	0 0 0	0 0	0 0	0 0	— <u> </u>
18 -	- 0 0 0	• •			*	0 0	0 0 0	-
12 -	0 0 0	• • •	•• •	0 0 0	0 0	0 0	0 0 0	-11
6 -		• • •	0 0 0	• • •	0 0 · · · ·	0 0	• • •	_
122 -	0 0 0		0 0 0	0 0 0	0 0	0 0	0 0 0	_
121 -				• • •	0 0			
119-					0 0			
116 -		0 0 0		000	0 0	0 0	0 0 0	G
113 -	0 0 0	• • •		000	0 0	0 0	0 0 0	
110 -	0 0 0	0 0 0	• • •		• •	0 0	0 0 0	bng
106 -	0 0 0	0 0 0		000	0 0	0 0	0 0 0	
103 -	0 0 0	0 0 0	0 0 0	000	• •	0 0	0 0 0	-11
- 101 -	-0-0-0	• • •	• • •	000	0 0	0 0	0 0 0	
								-
81 -			000	• • •	• •	-0-0-	0 0 0	-
52 -	0 0	. .	• • •	0 0 0	0 0	-0-0-	0 0 0	넙
51 -		-0-0	••••	•••	•••	-0-0	0 0 0	lan
48 -			0 0 0	0 0 0	• •	0 0		a
3/ -		0 0	0 0 0	0 0 0	0 0	0 0	0 0 0	
125 -	00 0 0	0 0	0 0 0 0	0 0 0	0 0	0		_
96 -	0 0 0	0 0 0		• • •	••	0 0	0 0 0	-11
95 -	0 0 0	-0 0 0	0 0 0	0 0 0	• •	0 0	0 0 0	-11
87 -	0 0 0	o o •	• • •	0 0 0	0 0	0 0	• • •	-11
86 -	0 0 0	0 0 0	0 0 0	0 0 0	• •	•		-11
76 -	00 0	0 0 0	• • •	• • •	• •	0 0	0 0 0	_ a
75 -	• • •	0 0 0	0 0	0 0 0	0 0	0 0 0	0 0 0	
74 -	•• •	• • •	0 0 0	0 0 0	0 0	0 0	0 0 0	-11
73 -	0 0 0	0 0 0	• • •	0 0 0	0 0	• •	0 0 0	-11
72 -	0 0 0	-	• • •	• • •	• •	0 0	0 0 0	-11
70 -	0 0 0	0 0	• • • •	0 0 0	0 0	0 0	0 0 0	-11
67 -	• • •	0 0 0	0 0 0	0 0 0	0 0	0 0	• • •	-
-	2010-01	2010-07	2011-01	2011-07 Date	2012-01	2012-0	07 2013	-01

GAM

A GAM model of the status against the day of the year was fitted with a binomial distribution, a logit link function and day of the year as a smoothing term with cyclic cubic regression splines.

GAM: predicted response



Cattle movements



Disease spread model of VTEC O157 in cattle



State transitions between the susceptible (S) and infected (I) disease states are modelled as a continuous-time discrete state Markov process (Gillespie's direct method)

$$S \stackrel{\upsilon \varphi}{\to} I$$
 (1)

$$I \stackrel{\gamma}{\to} S$$
 (2)

Environmental infectious pressure

$$\frac{d\varphi}{dt} = \frac{\alpha I}{N} - \beta \varphi + \varepsilon \tag{3}$$

Parameter estimation using an objective function

$$G(\theta) = \sum_{k} (\overline{\eta}_{k}(\theta) - \eta_{k}^{*})^{2}$$

$$\overline{\eta}_{k}(\theta) = \frac{1}{N} \sum_{N} \eta_{k}(\theta)$$
(5)



GAM: predicted response from simulations



Exploring spread on a national scale

initialisation from data 🗮 Uniform initialisation



Acknowledgements

- The Swedish Board of Agriculture and the Swedish Farmers' Foundatation for Agricultural Research (grant number V0930039) funded this work.
- ► The farmers and personnel at the regional livestock associations and the SVA laboratory are thanked for their cooperation in this research.
- This work was financially supported by the Swedish Research Council within the UPMARC Linnaeus center of Excellence (P. Bauer, S. Engblom).

Thanks

Questions?