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Using seasonal-trend decomposition based on loess (STL) to explore temporal patterns of pneumonic lesions in finishing pigs slaughtered in England, 2005-2011.

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1. Abstract.

Enzootic pneumonia (EP) is responsible for considerable economic losses in pig production. This study analyses temporal variations of pneumonic lesions present in slaughtered finishing pigs utilising a novel analytical tool – STL decomposition. Using data collected over a six-year period starting in July 2005, time-series analyses were conducted to identify trend and the presence of seasonal variations to support industry led measures to monitor and control this important respiratory disease. In England, the BPEX Pig Health Scheme monitors the occurrence of EP in slaughtered finished pigs by identifying its gross pathology, enzootic pneumonia-like (EP-like) lesions. For visual analytics, the monthly prevalence for EP-like lesions was modelled using STL, a seasonal-trend decomposition method based on locally-weighted regression. A binomial generalised linear mixed-effects model (GLMM), accounting for clustering at batch level, was used to test the significance of the trend and seasonality. A mean of 12,370 pigs was assessed per month across 12 pig abattoirs over the study period. A trend toward reduction in prevalence of EP-like lesions during the first three years of BPHS, followed by an increasing trend, was identified with STL. This feature was consistent with the presence of a

statistically significant positive quadratic term (“U” shape) as identified using the GLMM inference model. November and December appeared in the STL explorations as higher seasonal peaks of the occurrence of EP-like lesions. These two months had a significantly higher risk of this disease (OR = 1.38, 95% CI: 1.24 - 1.54 and OR = 1.4, 95% CI: 1.25 - 1.58, respectively, with July taken as baseline). The results were reported back to the pig industry as part of the national monitoring investigations.

Key words: pneumonia; pig-information systems; time-series analysis; seasonal dynamics

2. Introduction.

Respiratory disorders are regarded as the most serious diseases in modern swine production world-wide (Sorensen et al., 2006). Particularly in Great Britain, enzootic pneumonia-like (EP-like) lesions have been reported as the most prevalent respiratory condition detected through pig abattoir monitoring (Sanchez-Vazquez et al., 2010a). Although EP-like lesions are not pathognomonic for a particular pathogen (Sibila et al., 2009), *Mycoplasma hyopneumoniae* is usually involved in this pathology (Sorensen et al., 2006; Meyns et al., 2011). Substantial economic losses have been attributed to this infection including reduced feed efficiency, reduced daily weight gain and

3

increased production costs due to medication (Straw et al., 1989; Thacker, 2006). Since 2005 the BPEX Pig Health Scheme (BPHS) has monitored the occurrence of respiratory gross pathology in pigs slaughtered in England's main pig abattoirs. On a regular basis, swine veterinarians carry out detailed post-mortem examinations in parallel to the routine official food-safety meat inspections. BPHS offers consistent monitoring of the occurrence of EP-like lesions, which is used by the pig industry to evaluate the behaviour of national trends and to promote strategies leading to health recommendations aimed at addressing increasing trends, or to confirm favourable situations when the level of a disease is diminishing.

Understanding the temporal patterns of a disease is an essential step in learning about its epidemiology. Time-series analyses aim to provide a concise description of data correlated through time – serial correlation. Exploratory methods and graphical representations are integral to understanding the complexity of serially correlated data (Diggle, 1990). This is particularly true where the sample is equivalent to the population or a large sample size is available (where, for most practical purposes, the sample behaves approximately equal to the population), in which statistical inference is secondary in favour of descriptive methods. In this respect BPHS, with six years of consistent monitoring in English abattoirs, offers a unique opportunity to explore

 4

the temporal patterns of the occurrence of EP-like lesions. An exploratory method well-established in other fields is a seasonal-trend decomposition based on locally-weighted regression (loess) widely known as “STL” (Cleveland et al., 1990; Hafen et al., 2009). The STL method is straightforward to use, allows for flexibility in specifying the amount of variation in the trend and seasonal components of time-series, and produces robust estimates that are not distorted by transient outliers (Cleveland et al., 1990). In particular STL offers excellent data visualization – visual analytics – (Hafen et al., 2009). STL has been widely used in several disciplines including environmental science, ecology, epidemiology and public-health (Cleveland et al., 1990; Chaloupka, 2001; Silawan et al., 2008; Hafen et al., 2009).

This study analyses the six year trend of BPHS EP-like lesions and identifies the presence of seasonal variations, thereby investigating the progress (if any) made by the industry in controlling this respiratory disease. This paper presents a time-series investigation executed in two steps: firstly, visual analytics through STL are utilised to explore the temporal structure of this respiratory pathology; and secondly, an inference model, generalised linear mixed model (GLMM), is used to statistically test the significance of the temporal attributes. This paper is also intended as a reminder of the importance of data exploration in time-series analyses, and therefore places a particular

5

emphasis on describing the graphical exploratory process executed with STL.

3. Material and Methods.

3.1 Data source.

3.1.1 BPEX Pig Health Scheme.

BPHS has monitored the occurrence of EP-like lesions across the largest pig abattoirs in England since July 2005. Veterinarians assess every second pig in a batch (up to fifty pigs assessed) for gross pathology. The scheme feeds back benchmarked results from abattoir inspections to the participating producers (i.e. those paying a fee to be part of the scheme). The inspections, however, include all the batches submitted to the abattoir on the assessment days regardless of their BPHS membership status. More detailed information about BPHS can be found elsewhere (Sanchez-Vazquez et al., 2011).

3.1.2 Study sample.

This study used all (members and non-members) BPHS records available from the 12 abattoirs that participated in BPHS from July 2005 to June 2011. The abattoirs are geographically wide-spread across England (see Fig. 1). A total of 890,654 pigs (from 20,874 batches) has been assessed over this six-year period, submitted from

6

1,541 herds. The study data are the combined set of pigs assessed by BPHS.

3.1.3 The EP-like lesion.

EP-like lesions are reported for the following gross pathology: a red-tan-grey discoloration, collapse, and rubbery firmness affecting cranioventral regions of the lungs in a lobular pattern (Caswell and Williams, 2007). The lungs of every pig inspected were given a score that represents the approximate percentage of the parenchyma consolidated on a scale from 0 to 55. Because the aim of this study was to investigate the occurrence of EP-like lesions, a positive case was defined as a pig affected with any degree of lesion (score >0) and a negative when lesions were absent (score =0). This criterion has been used before to investigate risk factors associated with EP-like lesions (Sanchez-Vazquez et al., 2010a).

3.2 Modelling.

3.2.1 Time-series data.

The time-series was composed of monthly prevalence estimates, computed as the number of pigs affected with EP-like lesions, divided by the number of pigs assessed. The seasonal cycle was studied yearly (12 months), and for the seasonal cycle subseries comprised the set of

7

observations for a particular month across the six years (e.g. all the values for July, all the values for August, and so on).

3.2.2 Visual analytics, STL.

STL was utilized to model the EP-like lesions time-series of monthly prevalences. STL is a filtering procedure for decomposing a time-series into additive components of variation (trend, seasonality and the remainder) by the application of loess smoothing models (Cleveland et al., 1990; Chaloupka, 2001). Six parameters determine the degree of smoothing in the trend and seasonal components (Cleveland et al., 1990):

- n_p - the number of observations in each seasonal cycle.
- n_i - the number of loess smoothing iterations to update the trend and seasonal components (usually set to equal one or two).
- n_o- the number of robustness iterations. With a value of zero no robustness iteration is applied whilst values of one or more apply increasing robustness, particularly above 5. This parameter is chosen in combination with n_i.
- n_l - the span of the loess window for each subseries; it is recommended to use the next odd number to n_p.
- n_s - the span of loess window for seasonal extraction. Low values (e.g. from 7 to 10) favour the use of local data while higher

figures pool values from the equivalent time of the year across the time-series.

- n_t - the span of the loess window for trend extraction, typically computed as $[1.5n_p/(1\text{-}1.5n_s^{-1})]$.

The adequacy of the model fit was assessed by four graphical diagnostic methods: (1) the decomposition plot; (2) the trend-diagnostic plot; (3) the seasonal cycle subseries plot; and (4) the seasonal-diagnostic plot. Following Cleveland et al. (1990) and Jiang et al. (2010), a number of models were constructed using different parameter values and assessing the results against the diagnostic plots. Further information on the method and parameters can be found in the original paper describing the STL method (Cleveland et al., 1990). The need for data transformation was evaluated utilizing normal quantile plots of the residuals, ensuring its distribution is well approximated by the normal distribution (Hafen et al., 2009). Additionally, marginal residuals plots as described by Fraccaro et al. (2000) were investigated to identify any pattern that could be of concern.

3.2.3 Statistical inference, GLM/GLMM.

Batch EP-like lesions prevalence was modelled against time in monthly intervals. The ranges of season variables influencing the prevalence considered were monthly, quarterly and six-monthly. BPHS membership status and abattoir were also examined as covariates to account for their potential confounding effect. A simple binomial model, GLM, was used as a starting point; this evolved into a binomial generalised linear mixed-effects model (GLMM). In this latter model clustering at batch level, farm level, and both farm and batch were examined. Time was modelled as a polynomial function to allow for flexibility beyond a simple linear relationship, according to the findings observed in the visual analytics. The goodness of fit metric, Akaike's Information Criterion (AIC), was used for comparison among the different model structures and also to compare nested models through a stepwise selection process of covariates. The Wald tests were used to examine and present the significance (p value <0.05) of the variables retained in the final model, particularly for those with multiple categories (i.e. month, abattoir). Residual diagnostic plots were used to detect features of concern in the model and to identify the presence of potential outliers. The purpose of the inferential models was to confirm major trends picked up by STL and therefore only main effects were considered. All the analyses and graphs were performed using the R statistical software environment (R Development Core Team, 2009) using the libraries stats, epicalc and lme4.

4. Results.

The mean number of pigs assessed per month was 12,370 pigs (95% CI: 11,793 – 12,947), with a mean of 290 batches (95% CI: 276 – 304). Of those, the monthly mean number of pigs from BPHS members was 7,086 pigs (95% CI: 6,692 – 7,480) with a mean of 159 batches (95% CI: 150 – 168). A total of 252,941 pigs (from 18,387 batches) was affected with EP-like lesions across the whole study period which represent 28.4% of the total pigs inspected (28.7% of the members and 27.9% of non-members).

4.1 Results from the STL explorations.

Three of the parameters, n_s, n_i and n_o, required tuning through the use of the graphical diagnostic methods. For n_s 7 months was chosen, for n_i and n_o a robust option was chosen being 1 and 5 respectively. The other three parameters were predefined following the recommendations from Cleveland et al. (1990), being n_p=12 months, n_l=13 months and n_t=23 months.

The STL fitted trend was observed in the decomposition plot (Fig. 2a) in comparison with the raw data. It shows a decline in prevalence between 2006 and 2008; falling from 34% of the pigs affected to 27%, after which it started to increase reaching 30% in June 2011. In the trend-diagnostic plot (Fig. 3a) the trend is compared with the remainder, in graph (b) the two longest vertical lines in the remainder, one in March 2006 and other in December 2007, appear as outliers.

The STL seasonal component observed in the decomposition plot (Fig. 2b) suggests an increase of EP-like lesions in November-December, and a main drop in July. It also shows variation across years, with the seasonality being more marked over the last three seasonal cycles for most of the months. This interannual variation is more obvious in the seasonal cycle subseries plot (Fig. 4), where particularly for July and November, it is possible to appreciate the yearly seasonal values becoming more distant from 0 on the last three seasonal cycles. The seasonal diagnostic plot (Fig. 5) compares the fitted monthly values within the cycle subseries for each year with the remainder. This suggests the seasonal smoothing is robust to more outlying observations such as March 2006 and December 2007.

4.2 Results from the GLM/GLMM testing.

The model allowing for clustering in the data at batch level was the model that provided the best fit to the data. A quadratic term for trend (measured in monthly intervals) gave a better fit to the data (AIC=76,129) than a linear relationship (AIC=76,237). The results for the final multivariable GLMM are presented in Table 1. The estimated coefficient defining the quadratic term (16.37, 95% CI: 13.06 - 19.68) indicates that the trend for EP-like lesions followed a “U” shape. Compared to July (the month with the lowest prevalence acting as baseline), November and December had a significantly higher risk of EP-like lesions (OR = 1.38, 95% CI: 1.24 - 1.54 and OR = 1.4, 95% CI: 1.25 - 1.58, respectively). There were weak but significant differences between members and non-members, with non-members having a lower prevalence of EP-like lesions over the period studied, (OR = 0.94, 95% CI: 0.89 - 0.98). The inclusion of abattoir in the model improved the model fit, indicating significant differences in the risk of EP-like lesions between the different abattoirs compared to abattoir “A” that was taken as the baseline. Exploratory analyses of the residuals suggest that the chosen model was not inappropriate for the data.

5. Discussion.

This study has utilised the STL methodology to robustly identify the six year trend and seasonal pattern for EP-like lesions in finishing pigs in England. The data source was the BPEX Pig Health Scheme, which offered a large sample size of consistent abattoir monitoring providing a suitable opportunity to explore temporal patterns. By utilising STL, this paper maintains transparency in the explorations to identify the sources of variation in the time-series (i.e. the trend, the seasonality and a remainder). Both STL and GLMM results are consistent; thus, the inferential statistical testing assisted in confirming the findings from the exploratory process.

5.1 The trend and seasonality.

The GLMM identified a significant quadratic trend, which was described by STL as a decline in the occurrence of EP-like lesions between 2006 and 2008 (the first three years of BPHS), followed by a period of increasing prevalence. The occurrence of EP-like lesions results in important economic losses for the industry, particularly due to the worsening in feed efficiency and mean daily gain as a result of pigs being affected by EP (Straw et al., 1989; Straw et al., 1990). The initial prevalence reduction detected could, in principle, be attributed to the impact of the scheme on the overall health of the pig units. Veterinarians reacted to the feedback received for the prevalence of EP-like lesions, implementing measures to reduce it. These measures were conceivably extended to BPHS non-member herds, as has been discussed before (Sanchez-Vazquez et al., 2011). Moreover, non-members appear to have maintained a slightly lower level of disease than members. This apparently paradoxical situation could be also explained by the reluctance of some breeding units to join the scheme since they have their own abattoir monitoring system for respiratory diseases, and such herds are normally in good health and EP free. The reason behind the increasing trend over the last three years (which also corresponded to a more marked seasonal pattern) is unclear, but it could reflect a relaxation in the use of *M. hyopneumoniae* vaccines. The results from this study were fed back to the industry board, whose role it is to inform field veterinarians and producers of the current situation.

This STL investigation chose a small value to define the span of loess window seasonal extraction to allow for flexibility in the seasonality explorations for each year, rather than pooling the values for the same month across years, which could have potentially distorted the patterns (Hafen et al., 2009). The STL and GLMM results show the prevalence of EP-like lesions increasing at the end of the year (November and December) and declining in summer (July), a trend particularly obvious over the last three years. This pattern is consistent with that reported in most of the previous studies (Elbers et al., 1992; Stark, 2000) and that which has been observed in the syndromic surveillance of English growers and weaners (NADIS, 2008). Given that the life-span of EP lesions is at least two months, and that it could be detected as early as two weeks after infection (Caswell and Williams, 2007), the November-December peaks may be reflecting farm challenges occurring across the whole autumn (from September to December). Done (1991) explained how housed pigs may have poorer air quality due to reduced housing ventilation over colder months in the trade off for maintaining the indoor temperatures; a practice which may lead to an increase in the incidence of pneumonia.

5.2 STL in the context of time-series analyses techniques.

Time-series analyses, particularly those focussed on seasonal-trend decomposition, are scarce in the veterinary literature. Three of the most typical methodologies for which examples in the veterinary field can be found are: (1) moving average (MA) models (Arc Moretti et al., 2010), (2) generalised additive models (GAM) (Jore et al., 2010), and (3) linear regression (and its generalizations (GLM)) (Ward, 2002). MA is probably the simplest statistical technique available for decomposing time-series, and among these three techniques, is the only one directly comparable to STL as they are both filtering procedures. In MA, the filtered value is the averaged results within a predefined slide time-window producing a series of subsets with averaged values. In STL, the loess iterations are regulated by predefined parameters allowing the model to account for several factors (e.g. robustness, smoothing), offering more flexibility than MA models and providing a better fit to the data. The GLM and GAM belong to a different group of analytic techniques than STL. Those are inference models which allow the possibility of testing the statistical significance of the time components and accounting for different covariates. Change point models (Christensen and Rudemo, 1996) and Kalman filter (de Mol et al., 1999) are also examples of other methods utilised in the veterinary field to explore changes in time-series. These models are not designed to decompose time-series but are more focussed on optimising the detection of significant changes in the occurrence of an event of interest.

STL is presented here as an analytical tool for veterinary epidemiologists when tackling time-series explorations, being (i) a valid alternative to MA, (ii) a complementary method to GLM and GAM inference analyses, and (iii) a way to obtain temporal parameters that can be used to inform change-point and Kalman filter models. STL methodology produces robust outputs that provide a good fit to the data, maintains the transparency across the time-series decomposition (by examining the different diagnostic plots devised to work with this technique), and, what is perhaps its main strength, is ready and accessible for non-specialist analysts by utilising, for example, statistical packages that incorporate code to support the use of this methodology (e.g. STL function in R (R Development Core Team, 2009)). STL methodology was originally presented for count data but it has also been proved suitable to model binomial data in occurrence of disease as proportions (Bollag et al., 2005; Silawan et al., 2008), as has been presented in this paper.

Another typical objective when fitting models to time-series data is the prediction of future values. Jiang et al. (2010) compared STL with other widely-used methodologies to produce forecasting models with the presence of seasonal variation, seasonal autoregressive integrated moving average (SARIMA) and dynamic harmonic regression (DHR), concluding that the three methods are effective for time-series analysis.

5.3 Large scale monitoring schemes.

This paper is an extended example of the analyses that are periodically performed on the BPHS data to explore the time components of the different lesions investigated through the scheme. BPHS abattoir records have been considered to provide reliable trends (Stark and Nevel, 2009) and this system of detailed post-mortem inspection is presumed to have good sensitivity and specificity. A similar inspection system, also focused on a limited number of organs and pigs, was found to have good classification characteristics (Enoe et al., 2003). The presence of operator bias affecting the gross pathology classification over time cannot be ruled out; this is unlikely to happen, however, as BPHS organises training and refresher days for the veterinarians and conducts internal comparisons on the same pigs assessed by different veterinarians, aiming to maintain assessor consistency over time. On the whole, any imperfection in the scoring in this investigation could be considered randomly distributed over time and it would have been reflected in our study as statistical noise allocated in the remainder. The difference in prevalence of EP-like lesions observed across the abattoirs is likely to represent genuine differences across farm (clusters/geographical areas) due to the uneven distribution of specific respiratory pathogens or the effect of health strategies implemented by the different pig groups and veterinary practices (Sanchez-Vazquez et al., 2010a). In a previous investigation (Sanchez-Vazquez et al., 2010b), it was observed that BPHS participating abattoirs appeared to capture the pig shipments from neighbourhood farms.

The BPHS offers a very large sample size – an average of 12,370 pigs per month were assessed – and in this scenario, statistical inference is secondary in favour of descriptive methods. The larger the sample size the closer the sample will be to the population and the more likely it is to find statistically significant results in the inference models. This situation is demonstrated in this paper, where the temporal features extracted by visual analytics are consistent with those from the inference model, after accounting for the effect of other potential confounding covariates. The study population was those pig herds assessed over time by BPHS. However, these findings could confidently be extrapolated to the English commercial pig finishing units (i.e. the reference population), as the BPHS assessments are likely to be highly representative of the monthly cross-sectional disease prevalence occurring in these pig units.

6. Conclusion.

The evolution of EP-like lesions between July 2005 and June 2011 followed a “U” shape, with the initial reduction occurring during the first three years. The occurrence of this respiratory condition shows a seasonal pattern with the lowest level observed in July and peaks occurring in November and December. STL has a clear application in veterinary population medicine, particularly on national diseases monitoring, and it can be used in conjunction with inference models. This work shows an example of the utility of abattoir health schemes based on detailed post-mortem inspection as a large-scale health monitoring tool.

7. Acknowledgements.

We would like to acknowledge and thank John MacKinnon, who reviewed the manuscript, for his contribution with technical expertise on pig production. We are also grateful for the comments on the results of this study from Derek Armstrong (BPEX) and other pig experts participating in the BPHS steering group.

Figure 1. Map of Great Britain showing England shaded, with dots representing the location of the 12 abattoirs included in the study.

Figure 2. Decomposition plot of the prevalence of pigs affected with EP-like lesions in 12 English abattoirs (2005-2011), STL method. This plot assists evaluation of the trend, seasonality and remainder against the raw data. In the graph (a), the dots represent the monthly time-series for the proportion of pigs affected with EP-like lesions and the line is the STL fitted trend. The graph (b) is the STL seasonal pattern per 12 months. The values on 0 indicate no seasonal variation, as 0 represents an inflection point across the STL extracted trend; anything over 0 indicates increasing seasonal pattern (i.e. above trend) in the proportion of EP-like lesions and below 0 indicates decrease (i.e. below trend). The graph (c) represents the remainder after the trend and the seasonal pattern have been fitted to the time-series values. The sum of the trend, the seasonal pattern and the remainder equals exactly the time-series (dots in the panel (a)). The units in the vertical axis represent the proportion of pigs affected with EP-like lesions.

Figure 3. Trend-diagnostic plot of the prevalence of pigs affected with EP-like lesions in 12 English abattoirs (2005-2011), STL method. This plot assists to assess the fit of the trend to the data, which evaluates how much variation in the data other than seasonality goes into the trend and how much goes into the remainder - particularly useful for investigating the effect of the outliers on the trend. In panel (a) the points represent the STL fitted trend plus the remainder and the line is the STL trend. The panel (b) represents the remainder. The units in the

vertical axis represent the proportion of pigs affected with EP-like lesions.

Figure 4. Seasonal cycle subseries plot of the prevalence of pigs affected with EP-like lesions in 12 English abattoirs (2005-2011), STL method. This plot assists in assessing dispersion of each value of the cycle subseries against their mean; thus providing an assessment of the historical seasonal pattern as well as the temporal behaviour of each monthly subseries. Each cycle subseries is graphed separately against years (from 2005 to 2011); the month for each cycle subseries being indicated by its initial in the horizontal axis. The horizontal line is the mean of the STL fitted monthly values for each cycle subseries (values from Figure 2 graph (b)). The fitted values (ends of vertical lines) in relation to the mean show the pattern of the interannual variation of the monthly subseries. The units in the vertical axis represent the proportion of pigs affected with EP-like lesions.

Figure 5. Seasonal-diagnostic plot of the prevalence of pigs affected with EP-like lesions in 12 English abattoirs (2005-2011), STL method. This plot assists in assessing loess regression fit to the month across each year, evaluating how much variation in the data other than trend goes into the seasonal component and how much into the remainder. This plot helps to assess how the presence of outliers or transitional values with aberrant behaviour influences the results of the seasonal component. Each box represents a monthly subseries starting with January in the top left and progressing from left to right and from the top to the bottom. The initial for each month is used to identify the month in each box. The dots represent the STL fitted monthly values within the cycle subseries for each year, plus the remainder. The lines represent the STL fitted monthly values within the cycle subseries for each year. The units in the vertical axis represent the proportion of pigs affected with EP-like lesions.

Figure 1.

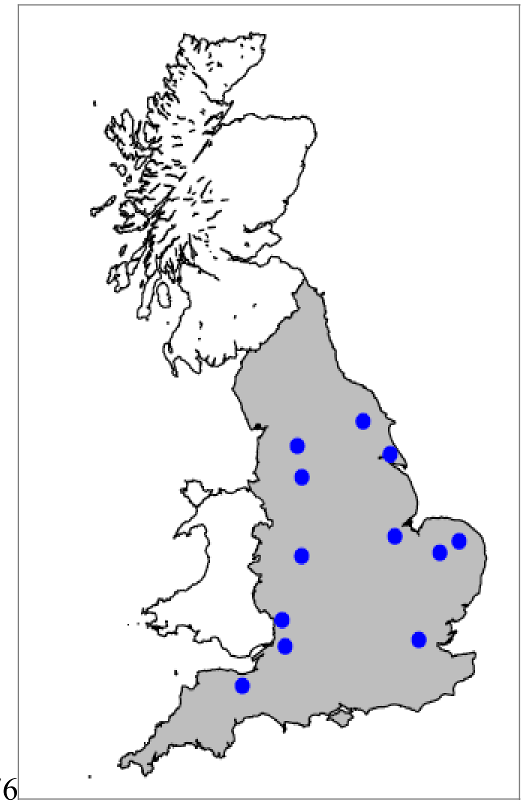

Figure 2.

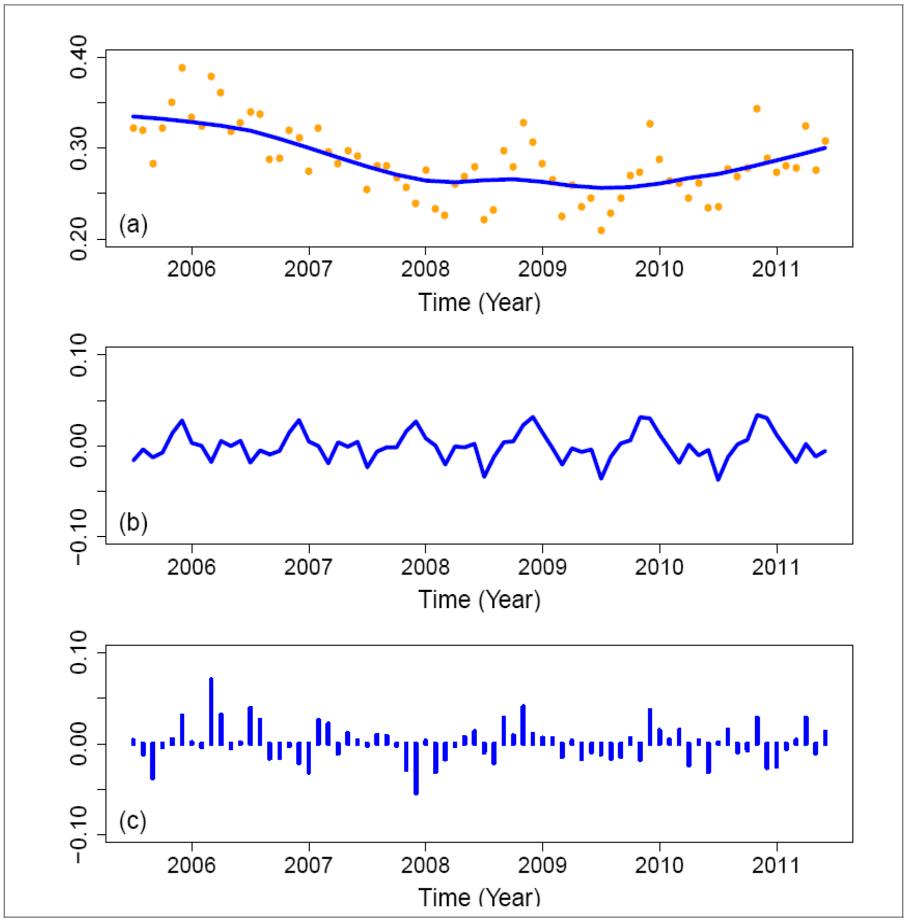
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Figure 3.

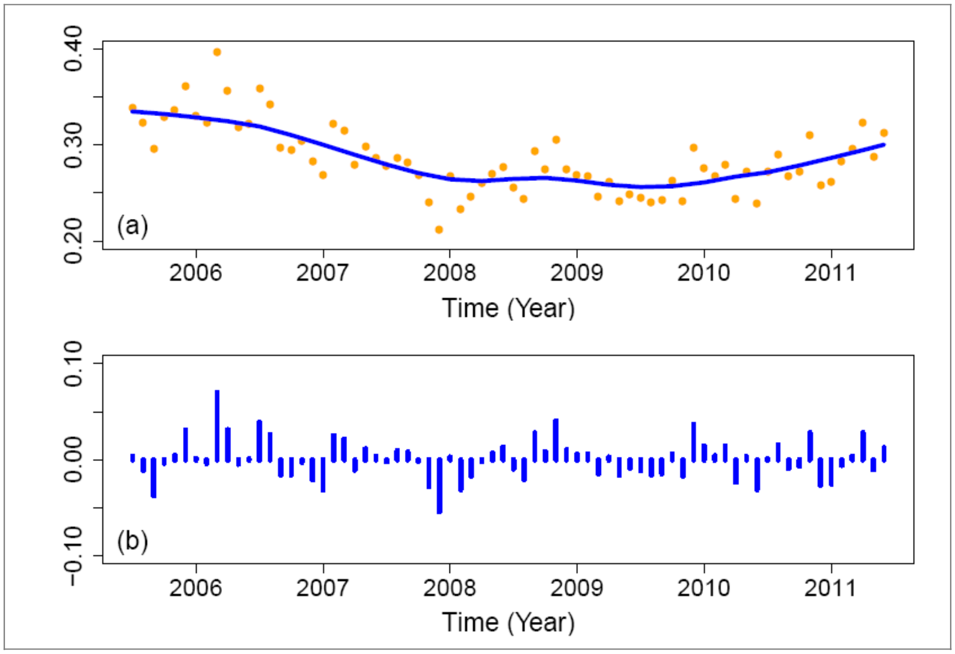
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Figure 4.

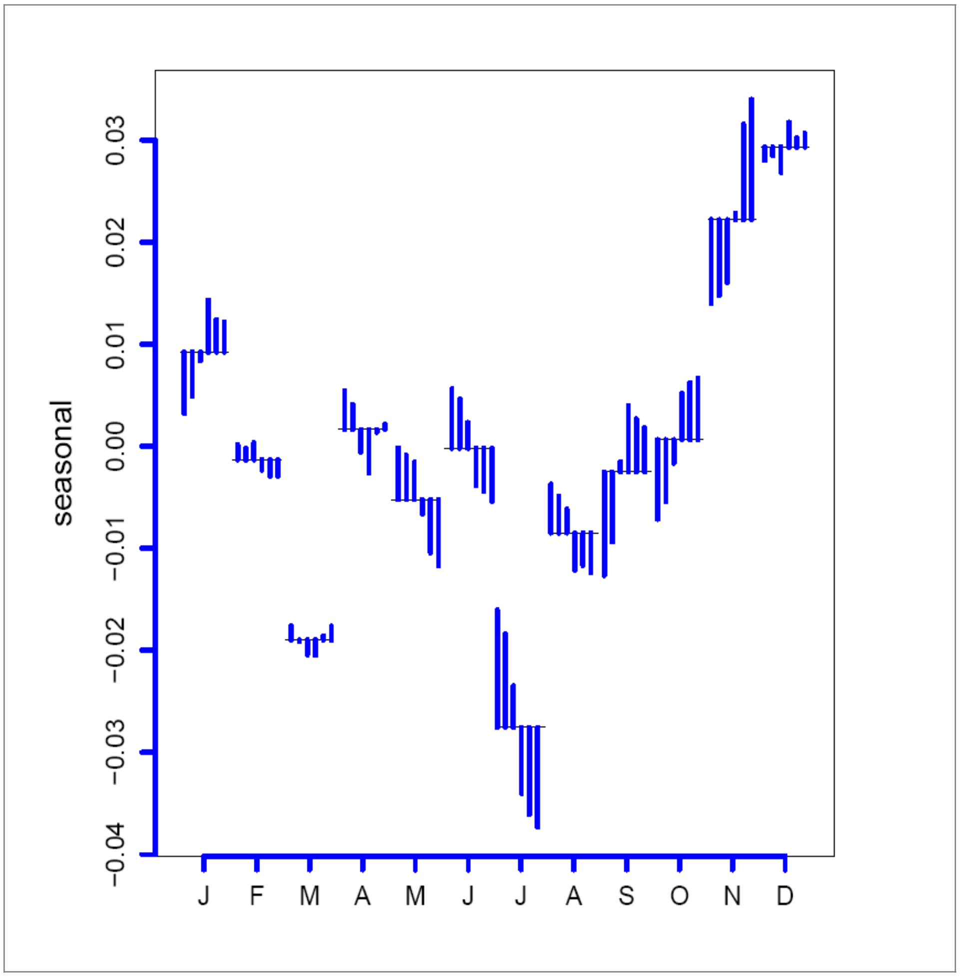

Figure 5.

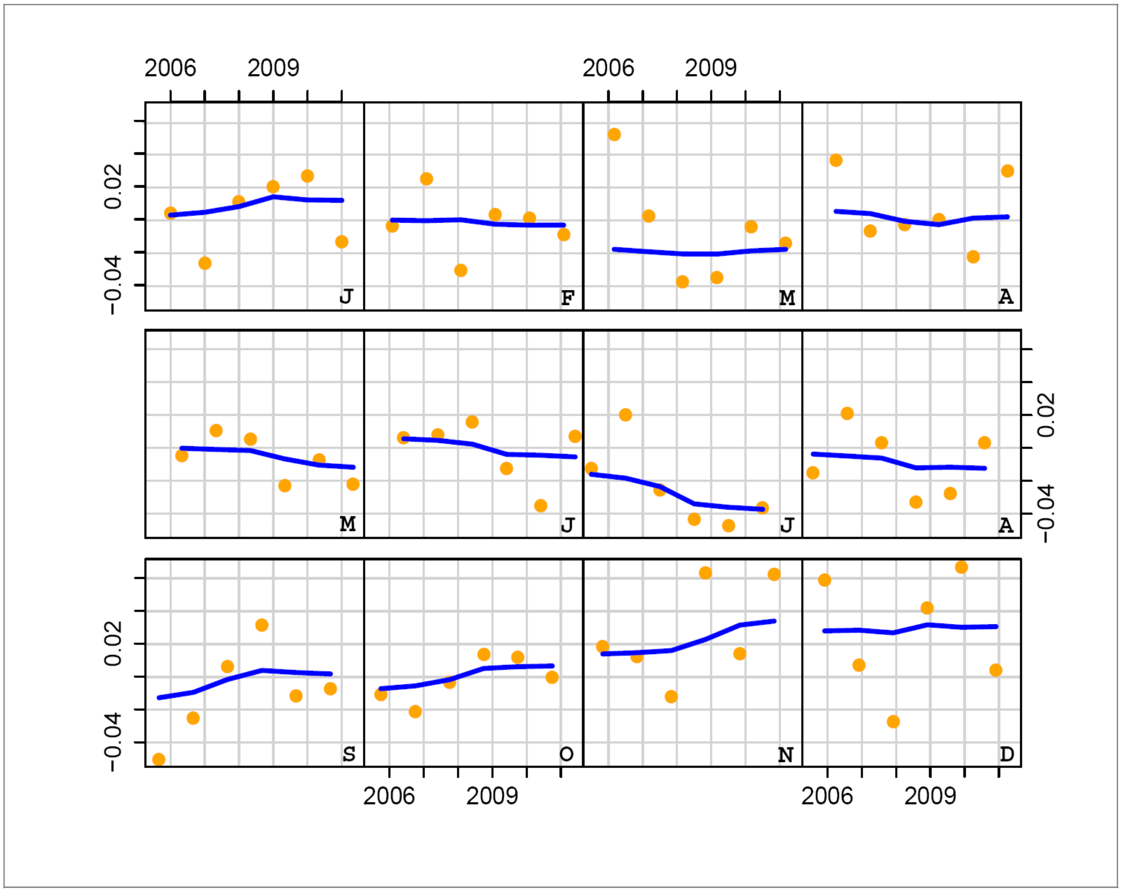

Table 1. Estimated coefficients for the linear and quadratic terms fitted to the temporal trend and estimated odds ratios for the covariates in the multivariable binomial generalized linear mixed-effects model for

the prevalence of EP-like lesions in finishing pigs slaughtered in English abattoirs accounting fro clustering at batch level, 2005-2011.

Variable For random effects	Variance	Standard error of variance component
Batch	2.42	1.56

Variables For fixed effects	Level	Estimate / Odds ratio	95% confidence intervals	P-value
Trend	Linear term	-16.18‡	-19.54, -12.82	<0.001
	Quadratic term	16.37‡	13.06, 19.68	<0.001
Month	July (baseline)	1	-	-
	August	1.12 Ŧ	1.01, 1.25	0.04
	September	1.14 Ŧ	1.02, 1.27	0.017
	October	1.17 Ŧ	1.05, 1.29	0.004
	November	1.38 Ŧ	1.24, 1.54	<0.001
	December	1.4 Ŧ	1.25, 1.58	<0.001
	January	1.28 Ŧ	1.15, 1.43	<0.001
	February	1.27 Ŧ	1.14, 1.42	<0.001
	March	1.16 Ŧ	1.04, 1.3	0.007
	April	1.27 Ŧ	1.14, 1.42	<0.001
	May	1.21Ŧ	1.08, 1.35	0.001
	June	1.19 Ŧ	1.07, 1.33	0.002
Being a BPHS member	Member (baseline)	1 Ŧ	-	-
	Non-member	0.94 Ŧ	0.89, 0.98	0.005
Abattoir	A (baseline)	1	-	-
	B	0.98 Ŧ	0.85, 1.14	0.818
	C	0.55 Ŧ	0.51, 0.61	<0.001
	D	0.44 Ŧ	0.35, 0.55	<0.001
	E	0.31 Ŧ	0.27, 0.35	<0.001
	F	0.34 Ŧ	0.31, 0.37	<0.001
	G	0.56 Ŧ	0.51, 0.61	<0.001
	H	0.6 Ŧ	0.53, 0.69	<0.001
	I	0.43 Ŧ	0.37, 0.5	<0.001
	J	0.66Ŧ	0.59, 0.74	<0.001
	K	0.4 Ŧ	0.36, 0.44	<0.001
	L	0.71 Ŧ	0.64, 0.78	<0.001

Model based in a sample of 890,654 pigs from 20,874 batches.

‡ Estimated coefficients for the linear and quadratic term (U shape) for EP like lesion trend.

Ŧ Odds ratios.