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Syndromic surveillance of influenza-like illness in Scotland during the Influenza A H1N1v pandemic and beyond

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Summary

Syndromic surveillance refers to the rapid monitoring of syndromic data to highlight and follow outbreaks of infectious diseases, increasing situational awareness. Such systems are based upon statistical models to described routinely collected health data. We describe a working exception reporting system (ERS) currently used in Scotland to monitor calls received to the NHS telephone helpline, NHS24.

We demonstrate the utility of the system to describe the time series data from NHS24 both at an aggregated Scotland level and at the individual health board level for two case studies, firstly during the initial phase of the 2009 Influenza A H1N1v and secondly for the emergence of seasonal influenza in each winter season from 2006/07 and 2010/11. In particular, we focus on a localised cluster of infection in the Highland health board and the ability of the system to highlight this outbreak. Caveats of the system, including the effect of media reporting of the pandemic on the results and the associated statistical issues, will be discussed. We discuss the adaptability and timeliness of the system and how this continues to form part of a suite of surveillance used to give early warnings to public health decision makers.

Introduction

As part of the preparedness for a possible outbreak of pandemic influenza Health Protection Scotland (HPS) developed a syndromic surveillance system to monitor and detect changes in levels of influenza-like illness presenting in the community. A component of this system used data from all calls made to NHS24. With the emergence of pandemic Influenza A (H1N1v) in April 2009 this system was developed further to provide real-time daily surveillance of NHS24 calls, tailored to the needs of the specific outbreak.

NHS24 is a nurse-led telephone helpline that is the means of access to out of hours general practice services for the Scottish population, approximately 5 million people (GROS, 2008), which began operating as a special health board in 2002 (The Scottish Government, 2002). NHS24 provides a similar service to NHS Direct which operates in England and Wales. Each weekday NHS24 receives around 2500 - 3000 telephone calls and on weekends and public holidays this rises to around 6000 - 7000 calls per

day. Peak levels of around 10000-14000 calls per day have been known to occur during the Easter and Christmas holiday periods when GP practices are closed.

The data provided from NHS24 facilitates syndromic surveillance in Scotland through an exception reporting system monitored at HPS. This system gives potential for real time monitoring of data and by generation of 'alarms' complements the suite of data available for situational awareness, namely attendance at GP practices, admissions to hospital, virological testing and deaths.

A range of factors influence the generation of 'alarms' including the size of an outbreak and the population affected the type of data being monitored. Syndromic surveillance systems have become more commonplace following their inception, mainly in the United States, as a (bio)terrorism surveillance tool based on emergency department admission records (Heffernan *et al.*, 2004, Fleischauer *et al.*, 2004). The validation of syndromic surveillance for the spread respiratory pathogens has also been demonstrated using multiple data registries (van den Wijngaard *et al.*, 2008). Elliot (2009) highlighted that "syndromic surveillance takes precedence as the primary means of estimating community burden of pandemic influenza infections", and syndromic indicators were used to monitor influenza activity in England and Wales during the pandemic (Smith *et al.*, 2011).

A Scottish multi-data source syndromic surveillance system, partly utilising NHS24 data, was implemented by Health Protection Scotland prior to the G8 summit in Gleneagles in July 2005 (Meyer *et al.*, 2008). These data were processed through a number of parallel exception reporting systems and reports generated daily for 10 syndromes considered relevant to possible bio-terrorism or disease outbreaks. Following the G8 summit the NHS24 stream of this multi data source ERS has been updated weekly. In the original version the syndromes were derived from data which was pre-categorised into syndromes by approximately 200 clinical algorithms at NHS24 – known as protocolled data. Due to operational changes at NHS24, the proportion of calls processed by the clinical algorithms at NHS24 fell to around 60-70% of calls, reaching lows of around 50% during busy periods with the remainder of the calls recorded in free text. This change provided the impetus to create a free text searching algorithm which classifies all calls received by NHS24 into one of the 10 monitored syndromes and an "other" category therefore allowing all calls to be analysed by the ERS. This development is particularly useful for periods when call numbers may reach peak levels e.g. in the event of mass illness such as pandemic influenza.

In this paper we describe the development of the ERS system to analyze all calls received by NHS24, in particular those associated with influenza-like illness. We present the results produced by the system at the beginning of the 2009 Influenza A H1N1v pandemic outbreak in the UK, the index cases of which occurred in a couple returning home to Falkirk, Scotland after a holiday in Mexico (*Scottish Government*, 2009a). From the date of the index case to the 1st July 2009, the UK pandemic was in an initial phase, whereby each possible case was tested virologically and all confirmed cases and close contacts were offered antivirals (HPA/HPS, 2009). This unique situation allows informal validation of the output of the ERS system to confirmed clusters of cases. In addition, we also describe the flexibility and timeliness of the system and the usefulness to decision makers during the outbreak.

We also illustrate how the system can be used to identify the start of the influenza season (outside of pandemic spread) in advance of alternative monitoring systems giving public health consultants and epidemiologists advance warning of possible clusters.

Methods

Data

The data provided to HPS by NHS24 includes the date and time of call, gender, age and postcode district available for each caller to the service. The data also records the call reason stated by the individual along with the protocol title(s) if the call is processed through the clinical algorithm process whereby the data which are pre-categorised into syndromes by approximately 200 clinical algorithms at NHS24. All calls have a free text entry whereas the proportion of calls which have a protocol syndromic category has ranged from 50% to over 90% over the period that the NHS24 ERS has been running.

By using postcode district as a proxy for the caller's location, calls are classified as originating from one of the 14 Scottish health boards, shown in Figure 1, allowing for surveillance at both the national and health board level, the latter being of particular importance for highlighting localised clusters of infection. Only the 11 mainland health boards are routinely monitored as the populations in the island health boards are small and the small call numbers originating from them make prediction unfeasible.

Prior to the Influenza A (H1N1v) pandemic data were received weekly, however in response to the outbreak, data receipt, processing and reporting of the findings occurred on a daily basis with results available by midday on the day of analysis for all calls received to NHS24 on the previous day.

Syndromic classification
For the NHS24 data, there are ten syndromic surveillance categories monitored as standard by the ERS system for both the protocol (where present) and call reason data streams. These syndromes are based on groupings of symptoms and are; colds/flu, coughs, fever, difficulty breathing, diarrhoea, vomiting, double vision, eye problems, lumps and rash. Four of these syndromes - colds and flu, fever, coughs and difficulty breathing - are specifically linked to influenza-like illness.

The pre-categorised protocol data are mapped to one of the 10 monitored syndromic surveillance categories or a generic "other" category. To enable classification of all calls in the call reason data stream into corresponding categories a free text searching algorithm was devised to interrogate the call reason field for each call record. Each call is classified, as outlined in Table 1, by searching for words associated with the syndromes, excluding certain combinations of words which may convey a different meaning and accounting for common misspellings. For example the word "cold" may be interpreted in a different way dependent on the words it appears with. Table 2 shows two calls to NHS24 and their eventual classification by the call algorithm. In the first, the call does not fall into any of the recorded syndromes and is therefore classified as other. For the second entry the keyword "cold" leads to a colds/flu

categorisation with the word "breathless" leading to the call also being classified as difficulty breathing. In this way each call is categorised as one or more of the ten monitored syndromes or "other" by the rule set.

The flexibility of the method, by which the free text searching algorithm interrogates the call reason field of the data, allowed a new pseudo-syndrome to be created which identified those calls mentioning the key word "swine". This term was of importance as Influenza A H1N1v was most commonly reported in the media as "swine flu", at the beginning of the pandemic.

Prediction Model

In most exception reporting systems some of the historical data are used to predict one or more future values. The observed future values are then compared to the predictions and if the observed value is sufficiently greater than the predicted value an exception is highlighted. This exception will then trigger an action by the epidemiologist or public health scientist to investigate. Reviews of exception reporting systems are given by Sonesson and Bock (2003), Farrington and Andrews (2004), Burkom *et al*. (2005), Buckeridge *et al*. (2005), and Shmueli and Burkom (2010).

The prediction model of the NHS24 ERS is based upon the over-dispersed Poisson linear regression approach of Farrington *et al*. (1996). This model was created to process weekly microorganism counts collated by the Communicable Disease Surveillance Centre in England and Wales and highlight possible disease outbreaks. This model made use of the trend in the counts in historical data spanning a 7 week period (centred on the current week of interest) over the previous 5 years. Such an approach aimed to produce a routine automated surveillance system which is timely, with good sensitivity and specificity and has readily interpretable outputs.

Examining the time series of total calls received to NHS24 over a typical non-pandemic period in Figure 2, it is clear that there is periodicity in the data with steady call numbers Monday-Friday and increases at the weekends when NHS24 is more heavily used as an out-of-hours service. Call numbers are also increased at public holidays, such as Easter and May Day illustrated. Adapting the model of Farrington *et al*. to include separate effects for weekdays, weekends and public holidays, allows for the development of a statistical model to predict the number of calls.

At the development of the system (Robertson, 2006; Meyer *et al.*, 2008) there was limited historical data – less than 6 months - to develop a more detailed prediction model in time for the G8 Conference and the use of 28 days of data was a pragmatic choice based upon guidance from the CDC Working Group (2004). For a given syndrome the count for day i is modelled using the data from day $i-4$ to day $i-31$. The preceding three days are excluded to limit the effect of large fluctuations or shocks, possibly attributable to random variation or the initial slow increase of an exception, which may bias the predicted values.

Mathematically for each syndrome, using the moving baseline data the expected count on day i, μ_i is modelled as a linear regression on time with separate intercepts for week days and weekend days as shown in Equation 1

$$\log(\mu_i) \sim \alpha_i + \beta_i \, weekday + \gamma_i \, weekend \qquad (1)$$
$$y_i \sim ODP(\mu_i), \quad Var(y_i) = \phi\mu_i$$

where β_i is the linear trend over the 28 day baseline and *weekday* takes integer values -4 to -31 over the 28 day period, α_i is the intercept corresponding to day i, γ_i is the effect on a Saturday or Sunday or public holiday, and y_i is the observed count on day i which is modelled as an over-dispersed Poisson, with dispersion parameter where

$$\hat{\phi} = \max\left\{1, \frac{1}{n-p}\sum_i \frac{\omega_i(y_i - \mu_i)^2}{\mu_i}\right\}$$

with the weight $\omega_j \propto \max\{1, r_i^{-2}\}$ and $r_i = \frac{3}{2\hat{\phi}^{1/2}} \frac{y_i^{2/3} - \hat{\mu}_i^{2/3}}{\hat{\mu}_i^{1/6}(1 - h_{ii})^{1/2}}$ where r_i are the standardised Anscombe residuals when $\phi = 1$ (Farrington *et al.*, 1996).

For each syndrome, given the observed number of calls from the data and the expected number of calls from the prediction model and taking into account over-dispersion to calculate an upper 99% prediction limit exceedance score is calculated according to the method of Farrington *et al.* (1996). Exceedance scores greater than 1 trigger an alarm marker indicating that the level of calls observed for that syndrome on that day exceeds what would be expected 99% of the time.

If a particularly large outbreak occurs, leading to increased call counts, then the increased counts become part of the data to model the trend, albeit down weighted according to the inverse of the squared residuals. If the down-weighting is not sufficient this can lead to a lag period when the model is unusable. This can be countered by simple adaptions to the baseline data used for predictions and potential ways to do so, including the use of historical data which has accumulated in years subsequent to model development, are considered. Use of historical data is centred 28 days on day i in the previous two years. This model is entitled "Two Years Historic". An adaption of this uses the same historical data but also uses data from days i-4 to i-31 to include recent trend which is entitled "Two Years Historic Plus 28 Days".

More complex prediction models have been investigated: Box Jenkins methods (Box and Jenkins, 1976); incorporating a temporal trend through Holt-Winters smoothing (Holt, 2006; Winters, 1960); incorporating spatial trends in adjacent health boards. There was a marginal improvement in prediction accuracy by including a Holt-Winters trend in the prediction model but this was not so great as to invalidate the simple model described above (Wagner, 2010).

Data Reporting

At each daily update, summary plots showing the time series and alarms generated for each health board/syndrome combination are produced along with a detailed list of the alarms triggered. The system is coded in R (http://www.r-project.org/) and is fully automated to produce all outputs. These results are then disseminated to the relevant public health consultants and epidemiologists at Health Protection Scotland. From

this information during the pandemic, daily and weekly situation reports were produced (HPS, 2009). These were distributed to health boards and to the Scottish Government with the NHS24 system providing a component of a suite of surveillance which aided the understanding of the current infection burden of influenza within the community.

Subsequent to the pandemic, daily extracts of data are still received. The system is run on a weekly basis and used in the weekly published Influenza update reports (HPS, 2011a). During peak influenza activity and during times of public health importance, such as the papal visit to Scotland in September 2010 and the Icelandic volcano eruption in spring 2010 (Elliot *et al.* (2010)), the system is run daily and the results analysed by consultants at HPS.

Results

Influenza A H1N1v pandemic

The time trend in the number of calls classified as the Colds/flu syndrome, by the free text search algorithm over the initial phase of the influenza pandemic is shown in Figure 3. Three distinct sets of concurrent alarms, where the observed number of calls exceeds the upper limit of what the model predicts as expected marked by the black dots, can clearly be seen in the observed colds/flu time trend at the Scotland level. The dates of the first two sets of these concurrent alarms correspond to four distinct events as indentified during the containment phase; the reporting of the UK index case in Falkirk in NHS Forth Valley, and three clusters of infection one in Dunoon in NHS Highland and outbreaks in Greenock and in Glasgow both in NHS Greater Glasgow and Clyde.

Examining the temporal trend in the proportion of calls to NHS24 which mention "Cold" or "Flu" as the call reason as shown in Figure 4, it is clear that there is a change point in the time series which corresponds with the confirmation of the UK index case of infection on the 27th April 2009. Analysis of the call records on the 27th-30th April, when the first four alarms where triggered, show that of the 849 calls classified as Colds/Flu 592 callers mentioned "swine" in their call indicating a possible association with the media reporting of a "swine" flu outbreak. Of those who mentioned swine, 64.5% did not go through the call algorithm process indicating either a medical emergency or that the protocol was not required as only information/advice was given. These callers were found to be less likely to have a protocol diagnosis than those not mentioning swine (64.5% vs. 30.4%, $p \leq 0.0001$) possibly indicating that a high proportion of these calls were of an advisory nature. As levels of infection in the community were low at this point and the majority of the calls mentioned "swine", the first group of alarms can be attributed to the effect of the worried well responding to media reports and official advice to contact NHS24 if concerned. This signal is evident not just in the Forth Valley health board, where the first cases lived, but also in the other two health boards illustrated – Highland and Greater Glasgow and Clyde – and over all Scotland emphasising that this exception is most likely due to the 'worried well' rather than those who have been in contact with symptomatic individuals.

The second sequence of alarms corresponds to the time of an outbreak in the Dunoon area which is in the NHS Highland health board and illustrated in Figure 3. In this case the alarms are likely to have been triggered by both actual cases in the area and the worried well in the area. The source of the outbreak was found to be linked to a football supporter's bus which travelled to and from a football game in on the 24th May. Two individuals travelling were confirmed to be infected with Influenza A H1N1v at the time of travel and subsequently infected 16 of the remaining 27 passengers. This event was followed by a rapidly growing number of cases within the town and the surrounding area. HPS received notification of the initial confirmed cases on the 29th May (HPS, 2011b). The first exceedances found by the system were on the 27th and the 30th May for colds/flu. These alarms were triggered prior to the exclusive news report by Scottish Television (STV, 2009) on 31st May which broke the story and the official press release from the Scottish Government on the 1st June (Scottish Government, 2009a) and was seven days prior to the peak of the call numbers in this area. Furthermore the signal is most evident in the Highland health board. Therefore these exceedances cannot be attributed solely to media influencing the worried well.

In addition to the alarms signalled in NHS Highland, there are also alarms signalled in NHS Greater Glasgow and Clyde, the first of which occurs on 13th May. This large-scale alarm followed three confirmed cases in a family residing in Greenock (part of NHS Greater Glasgow and Clyde) which lead to the precautionary closure of a nursery on the 12th May (Scottish Government, 2009b) and a primary school on the 13th May (Scottish Government, 2009c). Of the 109 cold and flu calls received from NHS Greater Glasgow and Clyde on the 13th May, analysis of the postal code of call origin indicated that 69.7% (76/109) of these calls were from Greenock postal codes and 31.5% (24/76) of these were for children under 11 years old (primary school age and below). Of the callers from the Greenock area with cold and flu symptoms on the 13th May, 93.5% mentioned "swine" in their call reason. Analysing the protocol diagnosis for all 76 callers, 17% had a colds/flu protocol diagnosis, 14% had an influenza-related protocol diagnosis of coughs, fever or difficulty breathing and 63% had no protocol diagnosis. Taken together, this alarm indicates an effect of the worried well alongside true infection in the community.

The scale of the alarm signalled on the 13th May in NHS Greater Glasgow and Clyde, led to the model over-predicting colds/flu call numbers in the two weeks which followed. During this time there was a cluster of infection in the south of Glasgow again leading to a precautionary school closure with news releases on 26th, 27th and 28th May (The Scottish Government (2009e) -(2009g)) . During this period there are increases in the number of calls observed but no alarms are signalled. The lack of alarms is due to both the over-predictions of the model and a smaller effect of the worried well. On the three days highlighted, there were 179 cold and flu calls received from NHS Greater Glasgow and Clyde and only 50% of these made reference to "swine", less than the proportion observed for the Greenock cluster earlier in the pandemic. The proportion with a colds/flu protocol diagnosis was also greater (28.5%) and less had no protocol diagnosis (26.8%). This may be indicative of a calming in the effect of the worried well as the pandemic progressed.

At the beginning of June there are a series of alarms triggered in NHS Greater Glasgow due to a gradual increase in the number of cases, as seen in the temporal maps in Figure 5, coupled with the over-prediction of the model subsiding.

At the end of the initial phase, as illustrated in Figure 5, all mainland Health Boards have confirmed cases with the majority in the NHS Greater Glasgow and Clyde, the most populated Health Board. The final set of alarms, after the initial phase ended, can be seen in the three Health Boards illustrated and at the National level. This is indicative of the spread of the pandemic over a wide geographical area in July which can be seen in the increasing General Practitioner consultation rates in this period (HPS 2009a).

Seasonal influenza

The above section has illustrated that the NHS24 ERS can respond in a timely fashion to outbreaks of H1N1v Influenza in local areas. The volume of the calls is greater than the number of people symptomatic during the outbreak and so represents a combination of sick and worried well calling. In Figure 6 we illustrate the correspondence between the system and the time trend in GP consultation rates outside of a pandemic period.

In the winter season 2006/07 the NHS24 ERS has a few alarms in mid October and the beginning of November corresponding to the rise in the GP consultation rates for influenza like illnesses and acute respiratory symptoms (Figures 6(*a*)). Alarms are also signalled in the period from mid December to the end of December and this precedes the sharp rise in consultation rates beginning in late December and peaking at the end of the first week in January 2007. In this season there is some temporal evidence that the syndromic surveillance system signals slightly before the effect on the health service.

Season 2007/08 did not have such a sharp peak in GP consultations as season 2006/07 but the peak again occurs in the first week of January 2008 with an earlier rise in the rates in late November 2007 (Figure 6(*b*)). The NHS24 ERS signals during the second week in November and again in the last week of December 2007. Both of these periods precede the rise in consultations by about one week.

Figure 6(*c*) shows that the agreement is not so clear in season 2008/09 where the peak in GP consultations appeared in the week before Christmas 2008. The NHS24 ERS signals four times in November and December which precede the increase in consultations in the week before Christmas. There are another two signals in late December and early January before the second peak in the second week of January 2008.

Season 2009/10 was the pandemic season and did not have the same winter pattern of a peak around about Christmas/New Year (data not presented). In the current season 2010/11 there were two signals before the first peak in late November 2010 but there were no signals to herald the beginning of the peak in GP consultations which came just before Christmas 2010 (Figures 6(*d*)) All the signals after this came when GP practices were closed for the Christmas holidays.

The comparison of the signals from the NHS24 ERS on colds and flu calls in relation to the GP consultation rates has demonstrated some consistent agreement with the ERS signalling about 1 week before the major rise in GP consultation rates; thus the system provides some early warning. However this was not always the case and in season 2010/11 the major peak was not signalled through NHS24 colds and flu calls.

Effect of variation of the 28 day baseline

The results presented in previous sections are based on using 28 days data to make predictions. Figure 7 summarises the results generated in the initial stages of the pandemic for the colds and flu syndrome over all Scotland using different baseline data.

In the original implementation of Farrington's model (Farrington, 1996) historical data from the same time in previous years was used. Results using two years historical data centred 28days on the equivalent date in previous years to that being predicted are shown in the plot titled "Two Years Historic" (Figure 7). If using only historical data, alarms are consistently generated over the entire period considered due to the call volume being considerably higher than in previous years. An adaption of the baseline, incorporating the previous 28 days with the historical data is shown in the pot titled "Two Years Historic Plus 28 days" (Figure 7). Such an adaption leads to an upward trend in expected call numbers and less volatile predictions, following large changes, than using the 28 days data alone. This leads to fewer alarms being generated in the period between the initial media reporting of the UK index cases and the first "true" outbreak at the end of May.

The period of over prediction in the original model following the media reporting of the outbreak could also be countered by using a more manual adaption without the need for historical data. By using a manually coded dichotomous variable to mark if an outbreak, or in this case an unprecedented high volume of cold and flu calls, is occurring the baseline 28 days data used can be altered to exclude the "outbreak" data and use the preceding 28 days "non-outbreak data". The results of this implementation with "outbreaks" defined as occurring between 27th April – 11th May and 30th May-31 July, is shown in the plot titled "28 Day Centred Outbreak Adjusted" (Figure 7). In this case, the model has no delay in usability "post-outbreak" and predicts a greater upward trend than the model using two years historical and 28 days data.

Discussion

The NHS24 syndromic surveillance system successfully detected exceedances in syndromes related to Influenza A (H1N1v) in advance of media reporting. This system was operating during the initial phase for Influenza A (H1N1v) whereby possible cases, who had known contacts with a confirmed case and were exhibiting symptoms of the virus, were given relevant treatment and advice and reported by either their health care practitioner and/or NHS24 call operatives to the emergency response team at Health Protection Scotland. In this situation the alarms triggered by the system did not require to be investigated as possible cases were already identified. The system did however provide useful information on the trends occurring within an

area and in particular reassurance with the lack of exceedances in areas where outbreaks were not known to be occurring.

Following the initial "containment" period, which ended on 1 July 2009, the flexibility of the system has proved useful in providing outputs not only to highlight areas where Influenza A (H1N1v) may be increasing and inform the relevant health boards of this, but also to provide a general understanding of both the levels of concern in the community via calls by the worried well. Monitoring of calls which mentioned "swine", not only gave an indication of the worried well but extraction of the raw call data and in particular the geographical location of the call aided epidemiological investigation during the containment phase. The value of the entire system in understanding the spread of Influenza A H1N1v in the community is discussed by HPS (2011b).

In a routine surveillance situation without epidemic spread, one of the main criticisms of syndromic surveillance is that there is generation of non specific signals or exceedances which may result in investigative action being taken unnecessarily (van den Wijngaard *et al.*, 2008). As exceedances in this system are generated at a nominal 1% significance level this indicates that there is a 1% probability that the observed number of calls is greater than the upper expected number of calls due to chance alone i.e. due to natural variability in call numbers (excluding any day of the week/holiday effect). It should be noted that this significance level is dependent on the weighting used, and in cases where the baseline values are down-weighted the value of the type I error will be higher. Such an exceedance occurring due to chance could therefore be classified as a false positive alarm.

On a given day of monitoring NHS24 by HPS each of the 11 syndromes is examined for 11 health boards and this is repeated for both the call reason and the protocol data. This means 242 exceedance tests are conducted each day giving approximately two expected false positive out all the health board / syndrome combinations per day and approximately 14 per week. However, there is no way to identify which exceedances are false positive and which are not and for this reason exceedances of note are generally looked for. A modification of the output could be to adjust the exceedances according to the false discovery rate approach outlined in Jones *et al*. (2008). Such an approach would favour the most extreme exceedances but is problematic for syndromes or health boards where the counts are low and small variation could lead to large alarms which may have very little epidemiological meaning. For the context of this surveillance it is therefore better to err on the side of caution and investigate possible false positive signals rather than increasing the exceedance limit.

The issue of false positive alarms is not restricted to multiple testing issues. The results presented clearly illustrate the influence which media reporting and the worried well can have upon the system whereby alarms are generated but not linked to any cluster of disease. False positives occurring due to the worried well are more likely in the call reason data stream. For this reason the subset protocol stream of calls, where an over the phone diagnosis has led to a syndromic categorisation of the call at NHS24, is also routinely monitored.

Modelling of public holidays is also problematic as areas within health boards (the smallest area considered) can have different local holidays which are not modelled

leading to a greater number of calls than predicted in that area and hence false alarm generation.

The role of the statistician monitoring the system is to identify exceedances and any patterns occurring. Any action required falls to the judgement of the consultant in charge. The protocol for dealing with the investigation of these exceedances is based on a number of factors which includes the nature of the exceedances; the magnitude of the exceedances and whether the exceedances are concurrent. The epidemiological determination of whether these exceedances warrant management as a signal indicative of further investigation then involves additional information on the detailed nature of the exceedances e.g. whether confined to a specific age group or sex, locality or whether the individuals required hospitalisation. A protocol developed by Meyer *et al*. (2008) which describes the process of management of any exceedances and identifies when subsequent investigation and escalation are required is routinely in operation at Health Protection Scotland.

Conversely, problems may also arise with the lack of alarms signalled in the time period following a large increase in the number of calls received to NHS24 for a particular syndrome, as indicated following the large exceedance in NHS Greater Glasgow and Clyde on 13th May. Under normal circumstances the weighting employed in the prediction model as instructed by Farrington *et al*., (1996) counters the effect of sporadic fluctuations in the baseline 28 days used to model the expected values. During pandemic spread however, the alarm system becomes less efficient as, following a chain of alarms where the observed count is substantially greater than expected, the baseline 28 day data predicts larger expected values and hence larger upper limits despite the down-weighting employed. The effect of these large values is slow to diminish if there are only small downward changes in the observed data and the alarm system takes time to recover. During this time, the system is useful to track temporal changes in the data by eye but the alarm system is less sensitive unless large upward fluctuations occur again. It can however be postulated that once epidemic spread begins in an area the signalling of alarms is pointless as the problem is apparent without the surveillance system. In the case of wishing to detect small changes over time, a differing methodology such as that based on control charts, may be preferable. For a full discussion of the various methods used in syndromic surveillance see Unkel *et al*. (2011).

In light of experience during the pandemic, alternative baselines have been considered. The current implementation is sufficient for small scale outbreaks but may not be robust if large scale changes occur. Results show that using only historical data limits the interpretability of fluctuations within an outbreak period as alarms are consistently signalled. In the absence of historical data, the over-prediction period could be avoided by using the most current data prior to the outbreak as baseline for predictions. This approach is, however, hindered by its manual nature and would require the outbreak period to be defined for a given syndrome in a given area which introduces subjectivity to the process. A more appealing choice may be to use a combination of historical data and the previous 28 days data. Such an approach modelled the upward trend in the data well and avoided the over-prediction spikes. Such an implementation would however require the omission of any outbreak periods, such as the pandemic, from the historical data to avoid inaccurate predictions. This could be introduced for future versions of the model.

Overall, the prediction model is simple and has been tested over the four years of operation of the system. Extensions to this model to take into account serial correlation, better trend estimation and spatial associations have been investigated, Wagner (2010), and while some of the extensions are useful their impact is not great. The most important development is to add an estimate of the term trend using a Holt-Winters estimate as a prediction term in the regression model which reduces the effect of serial correlation and increases the prediction accuracy.

The system has proven to be timely with the ability to update the system with a lag of one reporting day ensuring that up-to-date information regarding the current situation can be disseminated rapidly to NHS boards and local health protection teams.

Conclusions

The impetus to be able to make use of all calls to NHS24 rather than a possibly unrepresentative subset led to the development of a syndromic surveillance system based on a call reason interrogation algorithm. This system has been routinely used on a weekly basis to monitor influenza-like illness since 2006 and daily surveillance began when the Influenza A H1N1v pandemic was declared providing a timely up-to-date picture of the picture in the community to decision makers.

The exception reporting system highlighted the cluster of Influenza A H1N1v in the Highland health board and provided an indication of public perception of the outbreak i.e. the "worried well". The flexibility of the call reason interrogation algorithm allowed the analysis to be tailored to consider terms specific to Influenza A H1N1v and to extract relevant data for further epidemiological investigation.

The system has continued to be used throughout season 2009/10 on a daily basis and again in season 2010/11 on a weekly basis. In addition to tracking influenza-like illness in the community the system can also give reassurance that something is not happening as was the case during the G8 summit (Meyer *et al.*, 2008). More recently the difficulty breathing syndrome was tracked to give reassurances that the community was not experiencing any ill effects due to the volcanic ash cloud which was present over the UK following the eruption of the Icelandic volcano (Elliot *et al.*, 2010). It has also improved awareness during the recent Papal visit to Scotland and during an outbreak of Legionnaire's diseases in 2011.

The usefulness of the system, with an understanding of the caveats due to the influence of the worried well and the media, has led to the system forming part of the suite of surveillance provided to decision makers in government to help inform the community response to the Influenza A H1N1v pandemic and has continued to be used in season 20010/11 to monitor seasonal Influenza.

The system is not static and is continuously developed. Future developments will implement methods discussed which can improve predictability in the weeks after an outbreak occurs and also to consider modelling spatial correlation as discussed by Wagner (2010). The system is not specifically used for outbreak detection, and indeed there is no guarantee that all outbreaks will be detected but the main strength of the system is as a general monitoring system which along with other routine

surveillance systems used at Health Protection Scotland improves situational awareness and aids rapid investigation.

Acknowledgements

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FIGURES LEGENDS AND TABLES
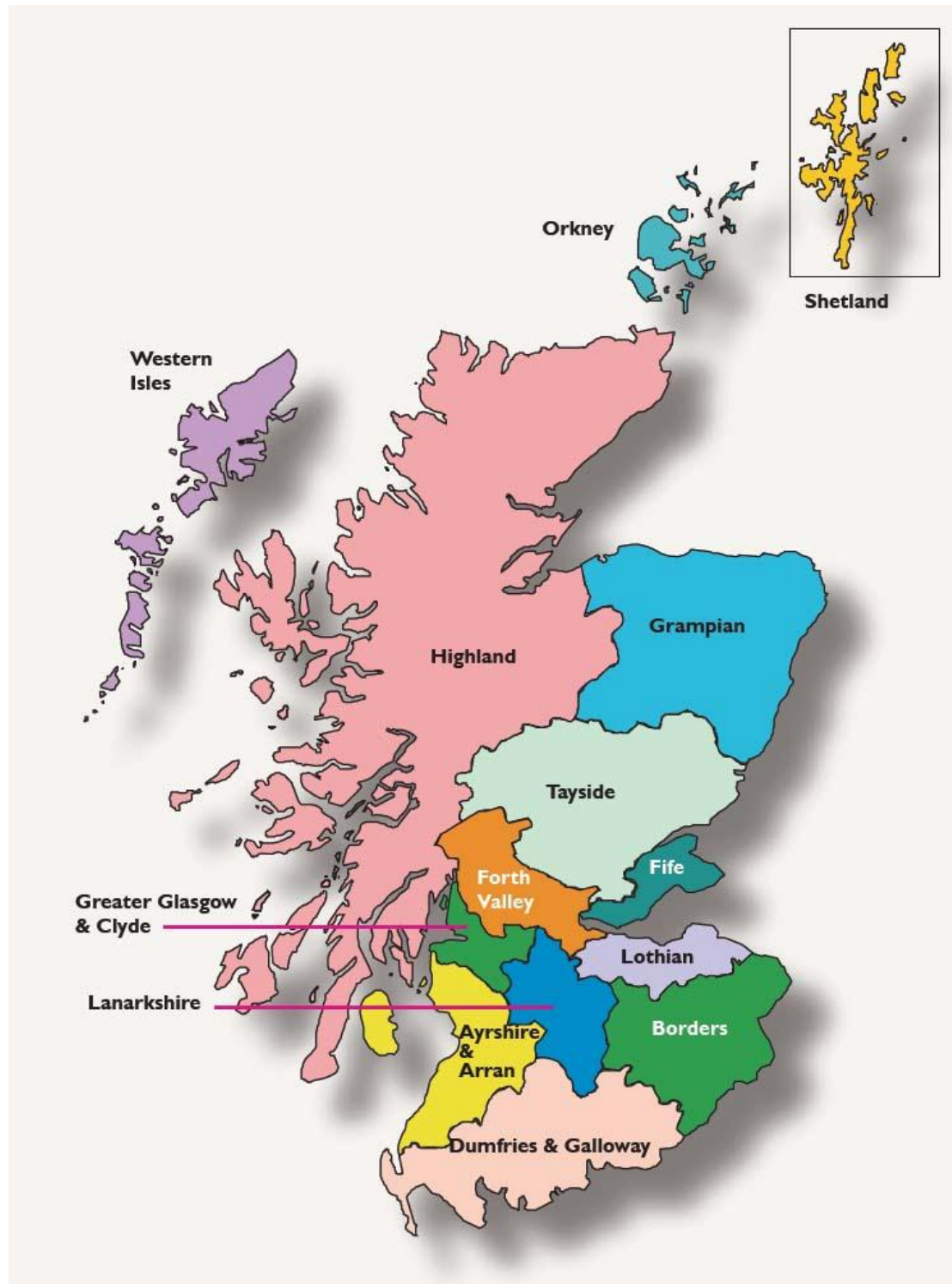
Figure 1: Illustration of the geographical location of the 11 mainland (and 3 island) health boards in Scotland (Source: Health Protection Scotland)
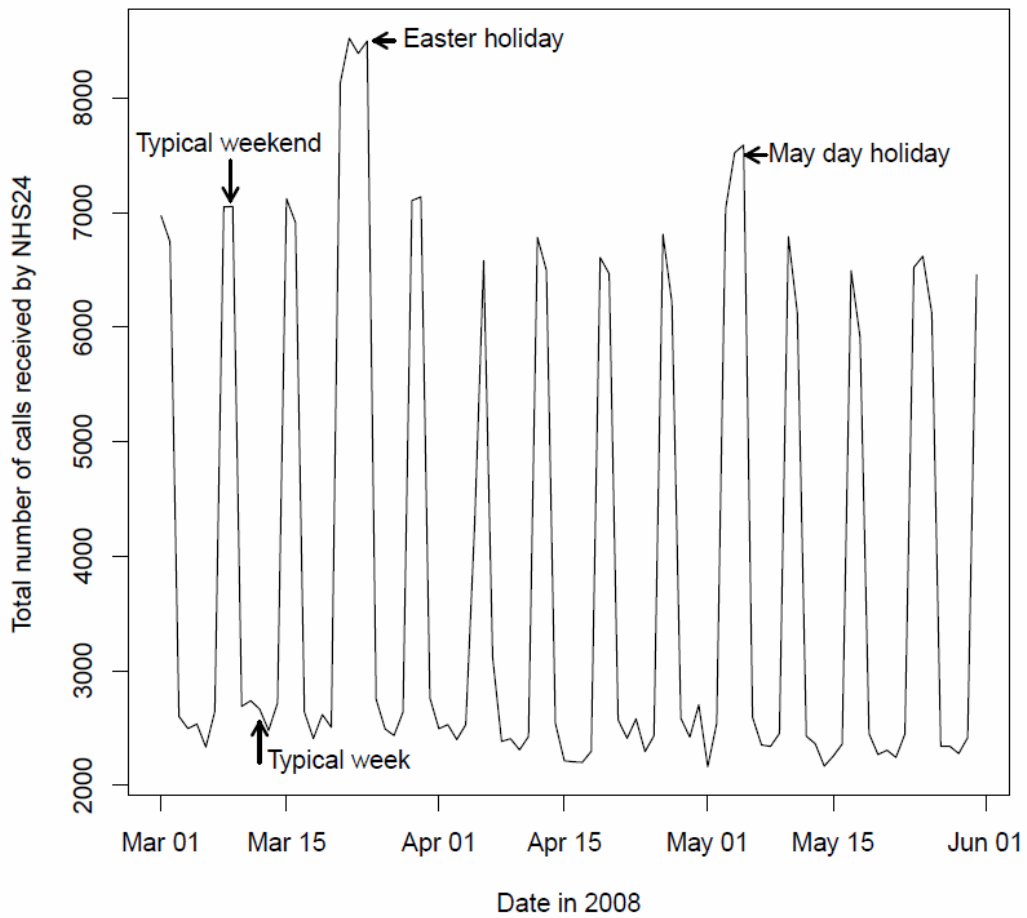
Figure 2: Time series of NHS24 calls in the period 1st March-31st May 2008 illustrating the typical periodicity in the call numbers with call numbers of around 2000-3000 calls on weekdays and 6000-7000 calls on weekends. The effects of public holidays at Easter and May Day can also be seen with call numbers increased further.
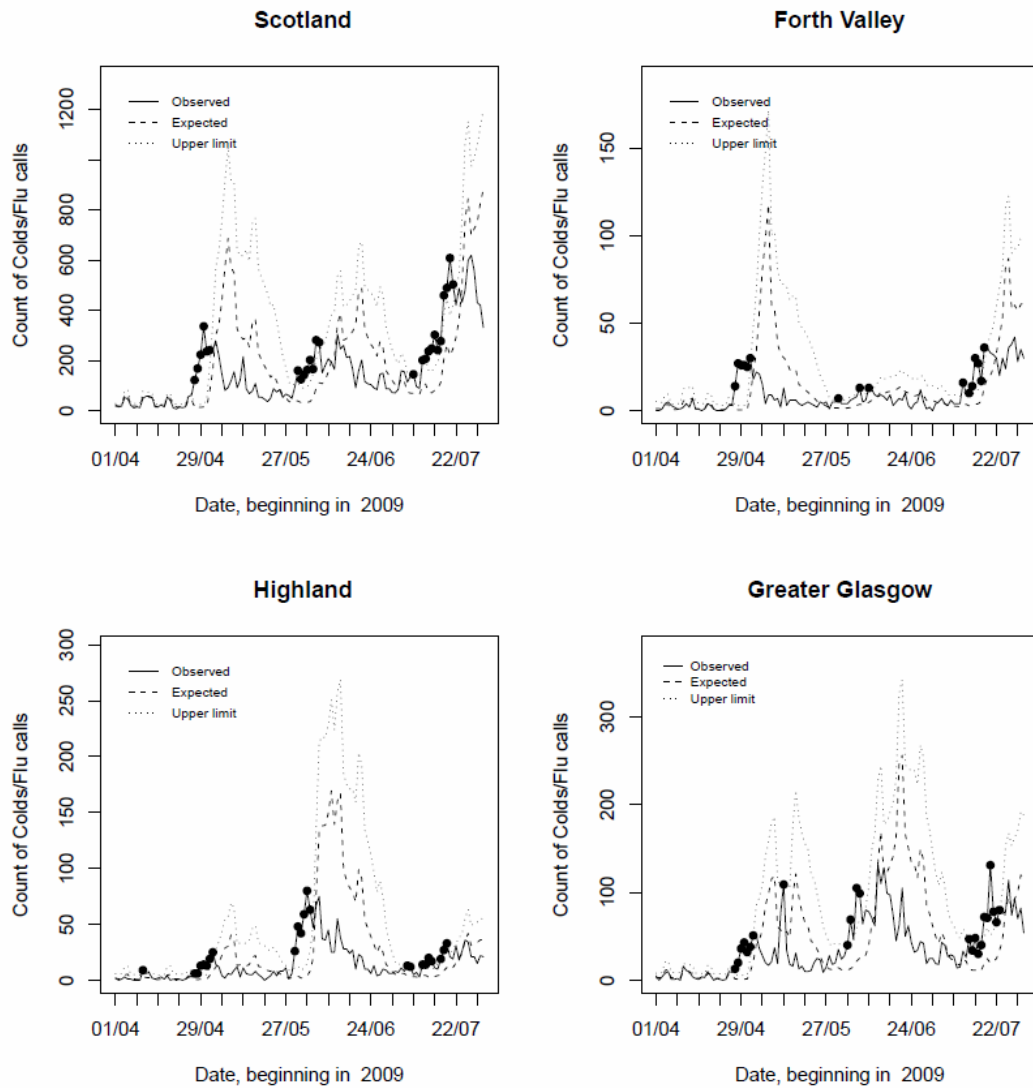
Figure 3: Cold and Flu syndrome calls at a national level and in NHS Forth Valley, NHS Highland and NHS Greater Glasgow and Clyde health boards monitored over the period 1st April -31st July 2009 following the UK index case at the end of April. The solid black line is the count of colds/flu calls received each day to NHS24 as classified from the call reason data. The dashed line is the expected number predicted from the model and the dotted line the predicted upper limit with a 1% significance level. The black dots represent the "alarms", i.e. points were the observed count exceeds the expected upper limit.
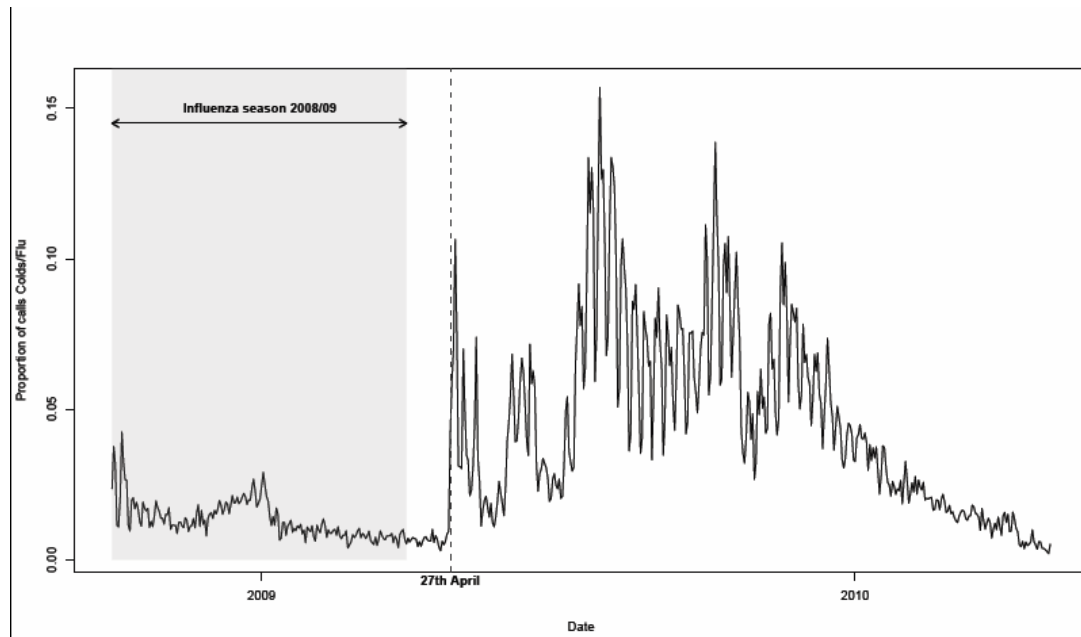
Figure 4: Proportion of all calls received to NHS24 which mention Colds or Flu in the call reason field from October 2008 to April 2010 (solid black line). The first UK confirmed case of Influenza A H1N1 was confirmed on 27th April 2009.
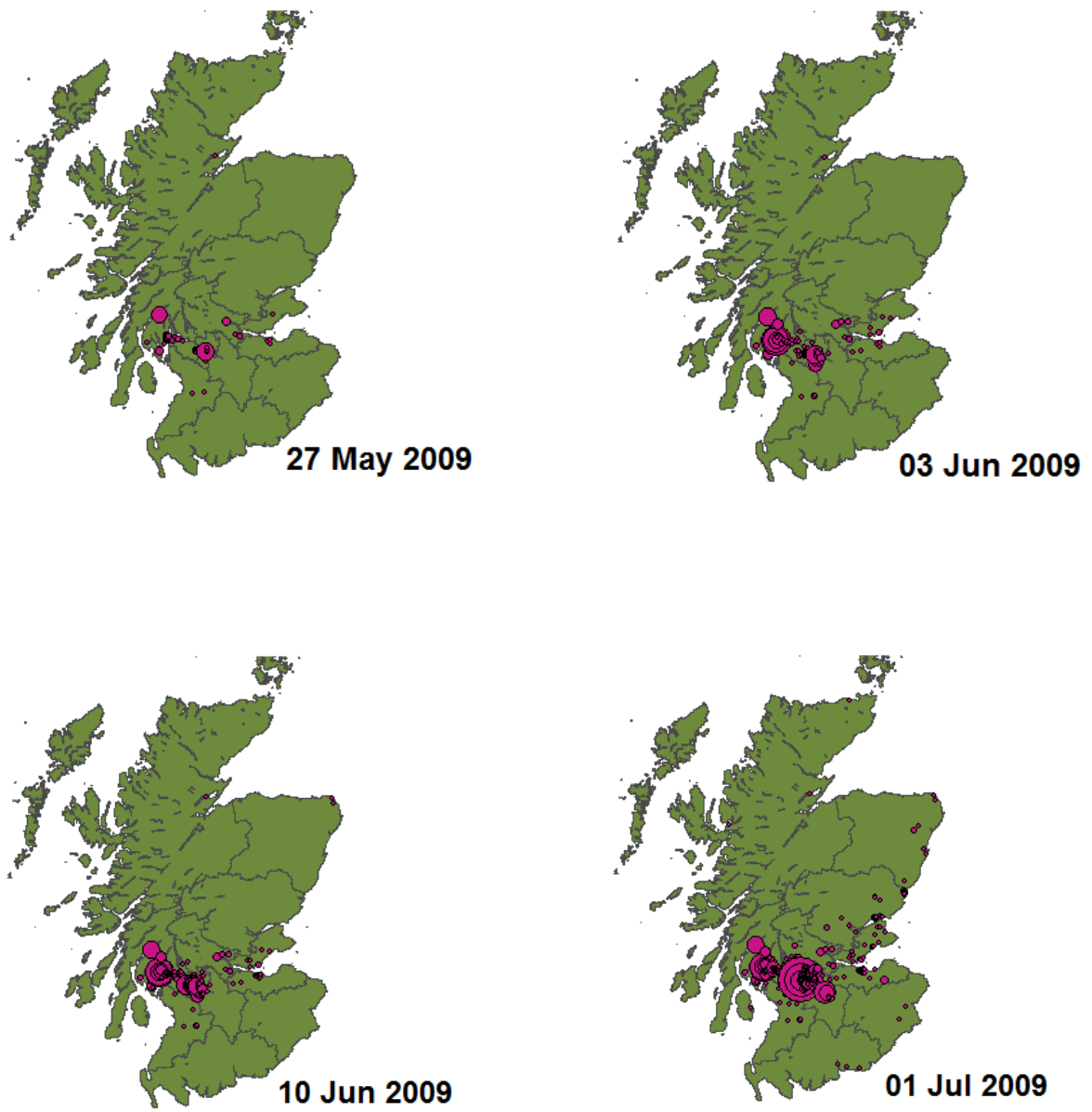
Figure 5: Spatial spread of laboratory confirmed cases of Influenza A H1N1v during the containment phase. Points are proportional to the size of the cluster in that area relative to the final number infected at the end of the containment phase.
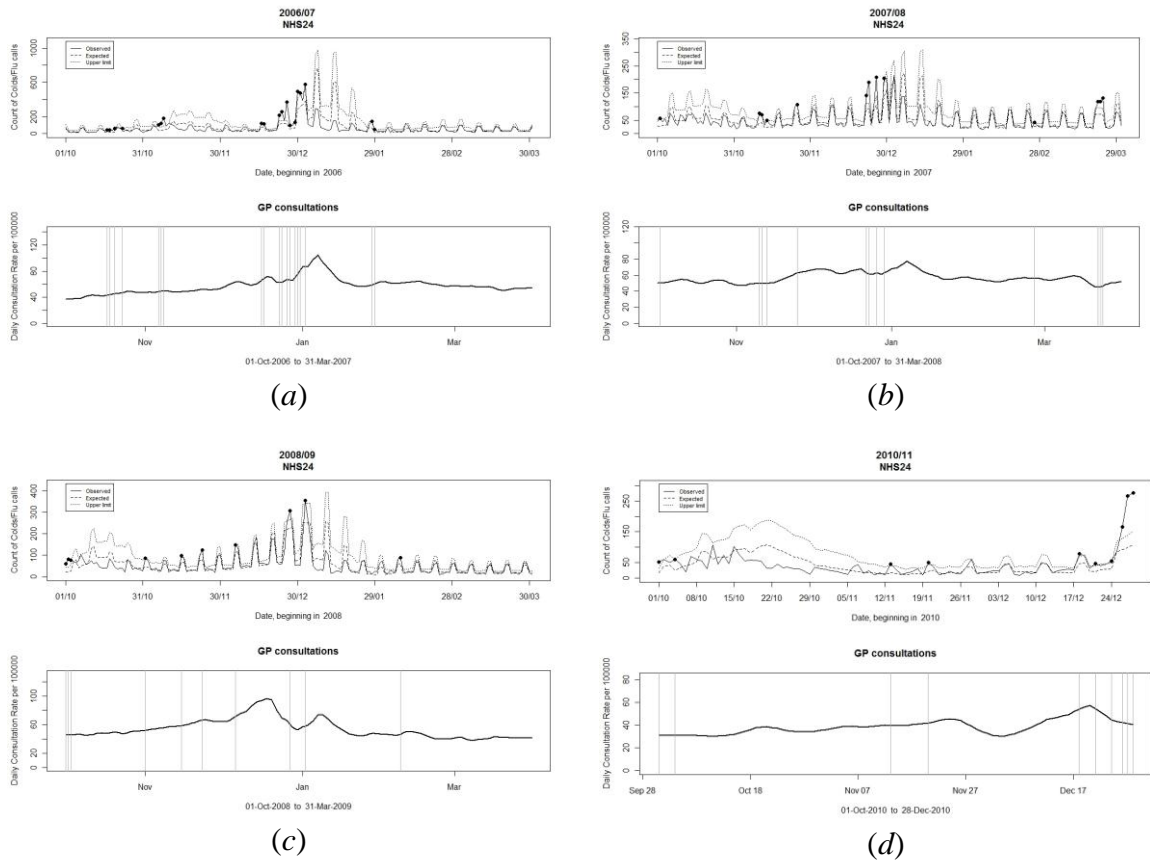
Figure 6: GP consultation rates and NHS24 ERS output for influenza seasons 2006/07 (*a*), 2007/08 (*b*), 2008/09 (*c*) and part 2010/11 (*d*) (note change of date scale). The vertical grey lines superimposed on the GP consultation rates indicate dates where the NHS24 signalled an alarm for the colds/flu syndrome at the National level.
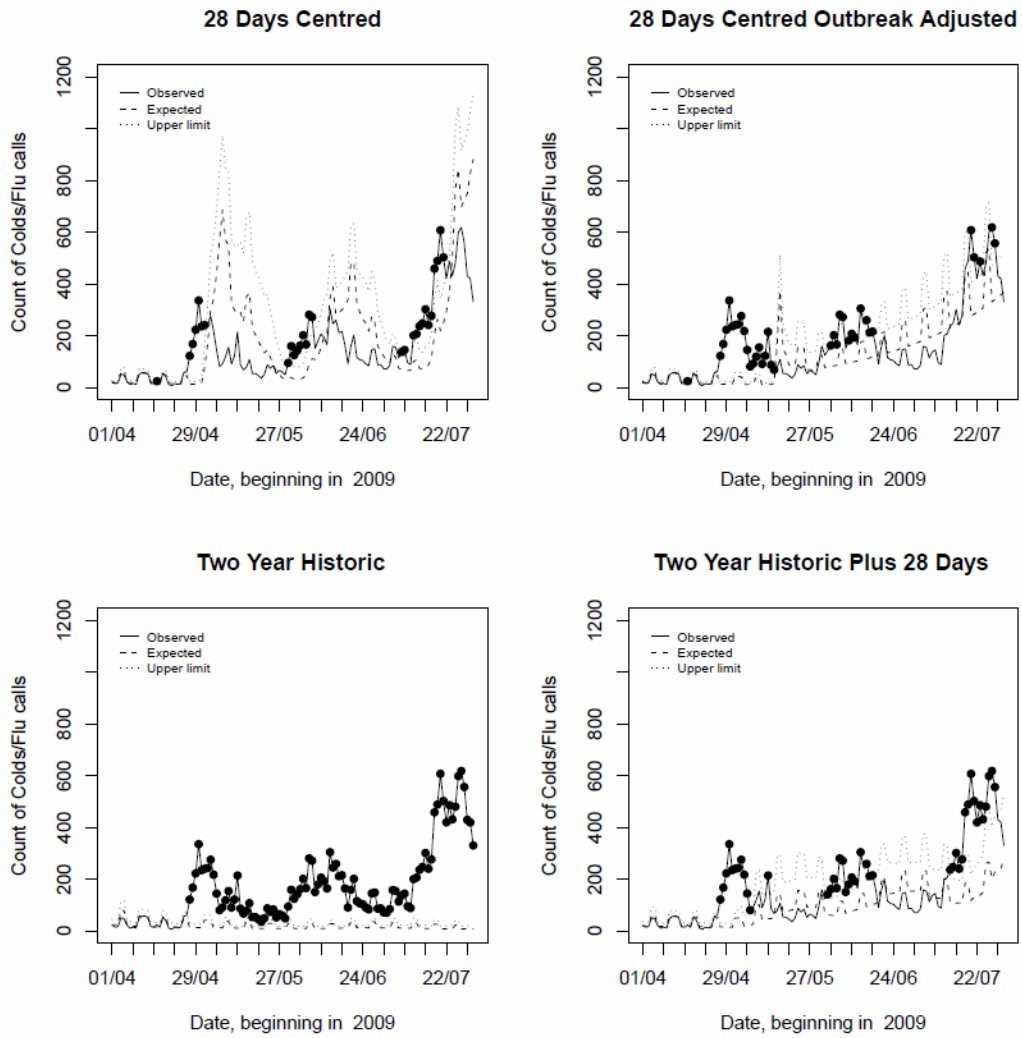
Figure 7: Comparison of NHS24 ERS output for the Cold and Flu syndrome calls across all Scotland over the initial period of the Influenza A H1N1 pandemic 1st April -31st July 2009 using different baseline data to make predictions.

Syndrome	Classification Rule
Colds/flu	Extract keyword "cold".Ignore cases with "cold" and any of the following: "sore", "hot", "hand", "leg", "shivery", "clamy", "sweat". Extract keyword "flu".Ignore cases where "flu" is part of a word i.e."reflux", "fluid", "flushed"
Fever	Extract keyword "fever" Extract keyword "temp" Exclude keyword "attempt"
Cough	Extract keyword "Cough"
Difficulty breathing	Extract keywords "breath", "wheez". Ignore any of those with "asthma attack"
Eye problems	Extract keywords "eye" and "dis" (discomfort, discharge) Extract keywords "eye" and "red" Extract keyword "visu" (visual disturbance
Diarrhoea	Extract keyword "diar" or "dior"
Lumps	Extract keyword "lump" and "neck" or "under arm" or "fac" (face/facial)or "groin". Extract keywords "swollen" and "glands".
Rash	Extract keyword "rash" Extract keyword "spot" Exclude "nappy" and "rash" Extract "chicken" and "po" (Rash may be called chicken pox by caller)
Double vision	Extract keywords "double" and "vision".
Vomiting	Extract keywords "vom" or "sick" or "nausea". Ignore those with any keyword and "blood" or "pregnant".

Table 1: Rule set for classification of the ten monitored syndromes from the free text call reason data entry.

Gender	Date	Postcode	Age	Call reason	Classification
Male	05/31/2007	KA19	83	**COLD** SWEAT, CLAMMY 20 MINS	Other
Male	05/31/2007	AB25	41	BREATHLESS, HEAVY **COLD**, SORE THROAT	Colds and flu Difficulty Breathing

Table 2: Example data with recognition of the word "Cold" in the call reason field and illustration of the resulting classification.