The effect of climate on Salmonella notifications in Queensland HHSs from 2001 to 2015

This project modelled Salmonella and Campylobacter notification counts using data from 2001 to 2015 following the approach of Zhang et al (2010).[1]

Zhang et al built a model to predict Brisbane and Townsville salmonella notifications from January 1990 to July 2005 (15.5 years) using climate data combined with a "year" and "season" variable. Data from 1990 to 2003 were used to build the model and the model was tested on actual counts from 2004 and 2005. For Brisbane and Townsville, respectively, weekly and monthly data was used.

In this project, climate and notification data was used to build a model for salmonella and campylobacter notifications in the Brisbane, Townsville, Cairns, Gold Coast and Sunshine Coast HHS regions. Data was obtained from the Bureau of Meteorology website at stations in major cities in each of the HHSs. In addition to the Zhang paper, a variable for population was added to the regression model, using population data from the Queensland Government Statistician's Office. [2]

Analysis was performed in STATA (version 14) and R (using the PEWMA (Poisson Exponentially Weighted Moving Average) package) as a test. These packages allowed for Poisson regression to be used to develop a model for predicting notification counts. PEWMA is a package developed by Patrick Brandt of the University of Texas, Dallas, to overcome some of the problems encountered using lagged count data in a Poisson regression model.[3]

Table 1 and Figure 1 show an example of the outcome of the prediction for Brisbane, using notification counts from 1, 2 and 3 weeks in the past, based on data from 2001 to 2013 and predicting 2014 and 2015. From approximately the beginning to the middle of 2015, the predicted number of events spikes to almost 300 in one week where the actual maximum notification count was 128 in weeks 1 and 3 of 2015. The highlighted coefficient in Table 1 indicates that each degree increase in mean weekly maximum temperature (all other parameters being equal) will lead to a 4.9% increase in salmonella notifications. The last two columns refer to the 95% confidence interval for each of the coefficients.

Table 1. Coefficients of Brisbane model with maximum temperature

Variable	Coef.	P-value	Lower CI	Upper CI
Count (lag 1 week)	0.014323	0	0.011906	0.01674
Count (lag 2 weeks)	0.004547	0.001	0.001934	0.00716
Count (lag 3 weeks)	0.004602	0	0.002068	0.007137

[1] http://climate.engin.umich.edu/Food_Water_Illness_Models/Zhang_Salmonella_Austral_Temp_Subtrop_SciTotalEnviron_2010.pdf

[2] http://qheps.health.qld.gov.au/hsu/InfoBank/infobank-demography.htm#estimated

[3] https://www.utdallas.edu/~pbrandt/pests/pests.htm

Maximum temperature	0.048669	0	0.041804	0.055534
Year	0.092977	0.002	0.034375	0.151578
Population	-1.72E-06	0.02	-3.16E-06	-2.75E-07
Season	0.092885	0	0.057619	0.128151
Constant	-182.517	0.002	-297.599	-67.4342

Figure 1. Prediction of Salmonella notifications in Brisbane in 2014 and 2015 using lag counts from 1, 2 and 3 weeks before, maximum temperature, year, population and seasonal effects

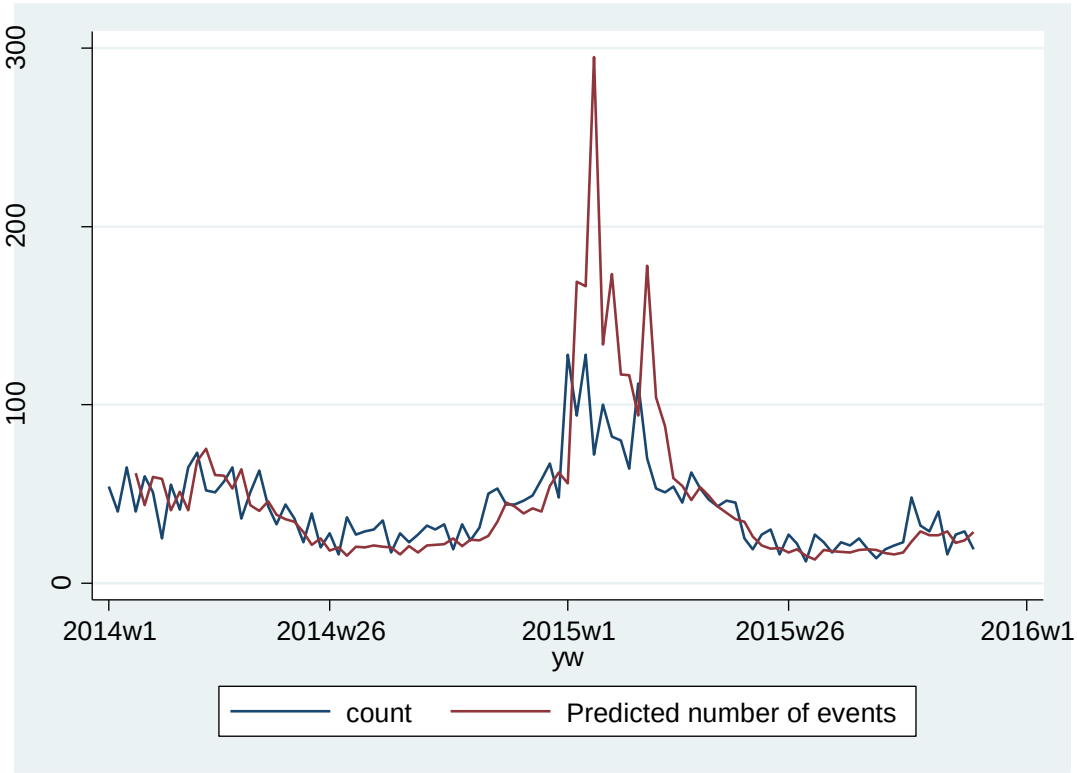


Table 2 and Figure 2 show the predictions for 2014 and 2015 using a model which takes only the previous week's notification counts into consideration. The volatility around the beginning of 2015 is much lower but still noticeable with the spikes in weeks 1 and 3 being used as predictors for subsequent weeks.

Table 2. Coefficients of Brisbane model with maximum temperature and one week lag

Variable	Coefficient	P-value	Lower CI	Upper CI
Count (lag 1 week)	0.01734	0	0.015208	0.019472
Max temperature	0.053711	0	0.04706	0.060361
Year	0.1049	0	0.0472	0.1626
Population	-1.89E-06	0.009	-3.31E-06	-4.63E-07
Seasonal variable	0.129425	0	0.096213	0.162637
Constant	-206.177	0	-319.482	-92.873

Figure 2. Prediction of Salmonella notifications in Brisbane in 2014 and 2015 using lag count from 1 week before, maximum temperature, year, population and seasonal effects

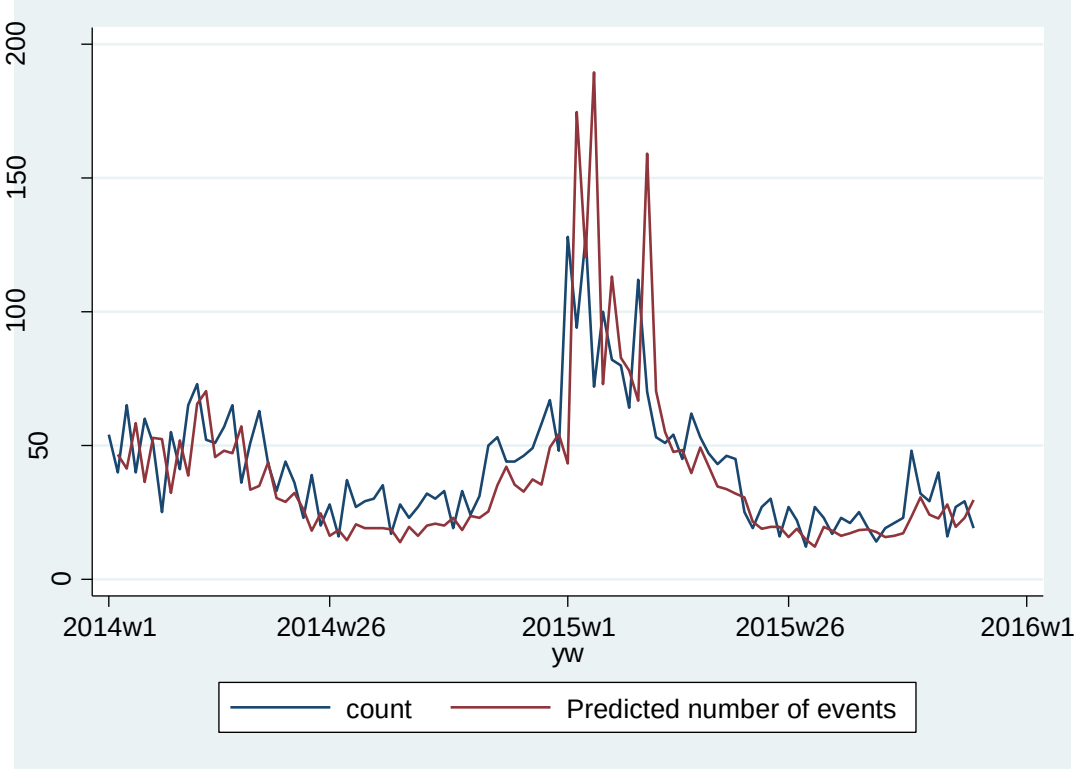


Table 3. Brisbane model with minimum temperature (two week lag)

Variable	Coefficient	P-value	Lower CI	Upper CI
Count (lag 1 week)	.0063864	0.000	.0049746	0.007798
Count (lag 2 weeks)	.0056491	0.000	.0043591	0.006939
Count (lag 3 weeks)	.0024746	0.001	.0010543	0.003895
Minimum temperature (lag 2 weeks)	.0556275	0.000	.0504099	0.060845
Rainfall	-.0011106	0.000	-.001527	-0.00069
Year	.2372671	0.000	.1851741	0.28936
Population	-4.90e-06	0.000	-6.20e-06	-3.61E-06
Seasonal variable	-.0417183	0.010	-.0733299	-0.01011
Constant	-465.9162	0.000	-568.1982	-363.634

The coefficients of each model indicate that for each degree increase in the mean weekly maximum temperature, all other things being equal, the number of notifications of salmonella is expected to increase by approximately 5% in Brisbane.

The model was also built for Campylobacter notifications and the main result is that the number of notifications of Campylobacter is expected to increase by approximately 1% for each degree increase in the mean weekly maximum temperature in Brisbane.

Table 4. Brisbane model for Campylobacter, using maximum temperature

Variable	Coefficient	P-value	Lower CI	Upper CI
Count (lagged 1 week)	.0121001	0.000	.0110531	0.013147
Maximum temperature	.0114434	0.000	.0077248	0.015162
Seasonal variable	-.057656	0.000	-.0770485	-0.03826
Year	.088439	0.000	.0546505	0.122227
Population	-1.96e-06	0.000	-2.81e-06	-1.11E-06
Constant	-171.1991	0.000	-237.5103	-104.888

Table 5. Brisbane model for Campylobacter, using minimum temperature

Variable	Coefficient	P-value	Lower CI	Upper CI
Count (lagged 1 week)	.0119995	0.000	.0109479	0.013051
Minimum temperature	.0096115	0.000	.006643	0.01258
Seasonal variable	-.0669126	0.000	-.0871417	-0.04668
Year	.0937046	0.000	.0598311	0.127578
Population	-2.10e-06	0.000	-2.96e-06	-1.25E-06
Constant	-181.3602	0.000	-247.839	-114.881

The Townsville models (as in Zhang et al) have higher coefficients compared to the Brisbane model – 9% for maximum temperature and 7% for minimum temperature.

Table 6. Townsville model with maximum temperature and 1 month lag.

Variable	Coefficient	P-value	Lower CI	Upper CI
Count (lag 1 month)	.0104011	0.000	.0058572	0.014945

Max temperature	.0938719	0.000	.0766761	0.111068
Seasonal variable	.2736803	0.000	.1867582	0.360603
Year	.1003988	0.004	.0320244	0.168773
Population	-.0000239	0.007	-.0000412	-6.52E-06
Rain	.0002777	0.007	.0000769	0.000479
Constant	-196.5652	0.004	-330.1682	-62.9622

Table 7. Townsville model with minimum temperature and 1 and 2 month lag

Variable	Coefficient	P-value	Lower CI	Upper CI
Count (lag 1 month)	.0104563	0.000	.0054085	0.015504
Count (lag 2 month)	.0055091	0.033	.0004316	0.010587
Min temperature	.0667353	0.000	.0538946	0.079576
Seasonal variable	.2514739	0.000	.1591306	0.343817
Constant	1.185704	0.000	.8621442	1.509264

Table 8. Cairns model with maximum temperature

Variable	Coefficient	P-value	Lower CI	Upper CI
Count (lag 1 month)	.0155192	0.000	.0092946	0.021744
Max temperature	.0938033	0.000	.0685954	.1190111
Seasonal variable	.1605363	0.000	.0763163	0.244756
Year	.1700752	0.002	.0610855	0.279065
Population	-.000041	0.002	-.0000663	-1.6E-05
Constant	-332.6247	0.002	-545.7375	-119.512

Table 9. Cairns model with minimum temperature

Variable	Coefficient	P-value	Lower CI	Upper CI
Count (lag 1 month)	.0191673	0.000	.0123712	0.025964
Min temperature	.0916413	0.000	.0680412	0.115241
Year	.1643407	0.004	.0528159	0.275866
Population	-.0000398	0.002	-.0000655	-1.4E-05
Constant	-320.6051	0.004	-538.738	-102.472

Table 10. Gold Coast model with maximum temperature

Variable	Coefficient	P-value	Lower CI	Upper CI
Count (lag 1 month)	.0094762	0.000	.0050748	0.013878
Max temperature	.089072	0.000	.0635418	.1146022
Seasonal variable	.0952787	0.043	.0027974	0.18776
Year	.0486117	0.000	.0320498	0.065174
Constant	-97.08956	0.000	-130.5977	-63.5814

Table 11. Gold Coast model with minimum temperature

Variable	Coefficient	P-value	Lower CI	Upper CI
Count (lag 1 month)	.0104241	0.000	.0063597	0.014489
Min temperature	.0805819	0.000	.0627222	0.098442
Year	.0389636	0.000	.0237551	0.054172
Constant	-76.80397	0.000	-107.4452	-46.1627

Table 12. Sunshine Coast model with maximum temperature

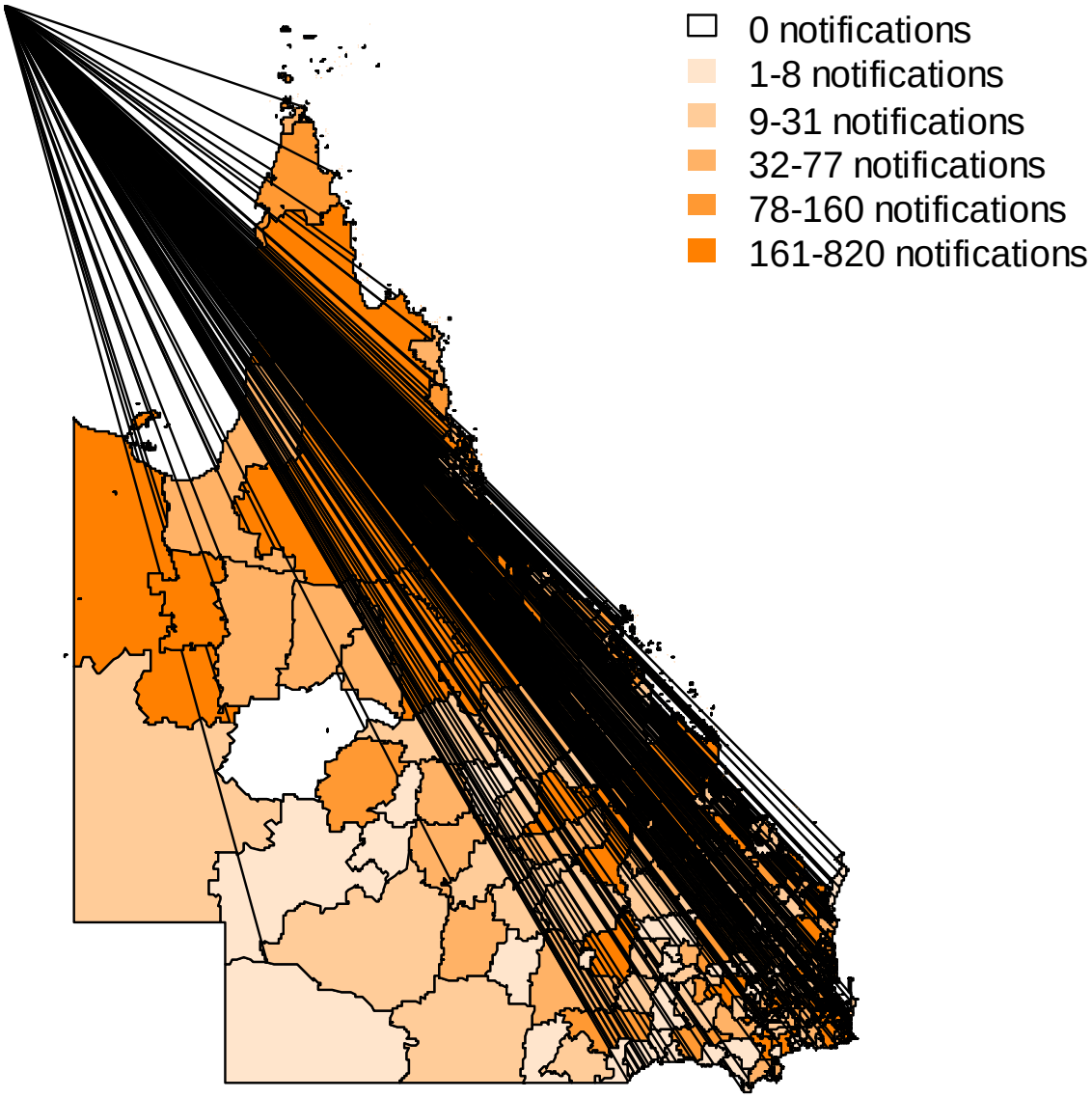
Variable	Coefficient	P-value	Lower CI	Upper CI
Count (lag 1 month)	.0103772	0.001	.0045295	0.016225
Max temperature	.088842	0.000	.0705661	0.107118
Year	.2395601	0.000	.1330684	0.346052
Population	-.000026	0.000	-.0000392	-1.3E-05
Constant	-471.8049	0.000	-681.213	-262.397

Table 13. Sunshine Coast model with minimum temperature

Variable	Coefficient	P-value	Lower CI	Upper CI
Count (lag 1 month)	.0092756	0.003	.0032138	0.015337
Min temperature	.0622387	0.000	.0502408	0.074237
Year	.2496537	0.000	.1397748	0.359533
Population	-.0000264	0.000	-.0000401	-1.3E-05
Constant	-490.6415	0.000	-706.6387	-274.644

Finally, Figure 3 shows a map of Salmonella notifications by postcode from 2001 to 2015.

Figure 3. Map of Salmonella notification counts for Queensland from 2001 to 2015.



Conclusions

Across the five HHSs examined, it was consistently found that each degree increase in mean weekly or monthly maximum or minimum temperatures would lead to an increase of 5% to 10% in salmonella notifications based on 2001 to 2015 data. This is very similar to the results of Zhang et al based on 1990 to 2005 data.

Further research could involve looking at population aged 0-4 in each region as a predictor variable as this age group accounts for the largest proportion of cases of any age group.

A better predictor variable than climate data may be consumption patterns of chicken and eggs in each of the regions over time, considering both the absolute and seasonal components. The team does not have any data on seasonal consumption of possible infection vectors, but Woolworths sales

data available from Quantium accounts for approximately 40% of the retail food market and should be a good proxy for actual consumption in these larger HHSs.