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SHORT REPORT
Spotted Fever Group Rickettsioses (SFGR): weather and incidence in Illinois

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Summary

The purpose of this study was to identify predictors of increasing incidence of Spotted Fever Group rickettsioses (SFGR) in Illinois, with a specific focus on weather variables. We analysed cases of SFGR reported to the Illinois Department of Public Health from 2004 to 2013. Surveillance definitions changed in 2008 and 2010, but those changes alone did not account for observed spikes in incidence in 2008, 2012 and 2013. A total of 590 cases of SFGR occurred, with the majority in the southernmost portion of the state. Only 3·4% of the reported cases were considered confirmed under the case definition. Increased mean winter temperature (IRR 1·32, CI 1·25–1·40) and increased precipitation (IRR 1·08, CI 1·04–1·11) were each associated with increased incidence of SFGR. Our findings show that weather appears to play a significant role in explaining the increasing annual incidence of SFGR in Illinois.

Key words: Infectious disease control, infectious disease epidemiology, notifiable infectious diseases, rickettsiae, zoonoses.

The Spotted Fever Group rickettsioses (SFGR) are a group of tick-borne bacterial diseases that have increased in incidence from less than two cases per million persons to greater than 14 cases per million persons in the USA from 2000 to 2012 [1]. Rocky Mountain Spotted Fever (RMSF), the most common SFGR, is mainly transmitted in Illinois by the *Dermacentor variabilis* tick [2]. RMSF typically causes a rash, fever and myalgia, and can be fatal without early treatment [2]. Other SFGRs causing illness in the USA include *Rickettsia parkeri*, transmitted by the *Amblyomma maculatum* tick, and *Rickettsia* species 364D, transmitted by the *Dermacentor occidentalis* tick [2]. As the number of cases reported nationally has increased, the number of SFGR cases in Illinois has also increased over the past decade, with spikes in cases in 2008, 2012 and 2013. The increase in Illinois is unlikely due to *R. parkeri* or *Rickettsia* species 364D as the range for the tick vectors of these *Rickettsia* species does not currently include Illinois [2].

RMSF has been a nationally notifiable disease since 1944 [3]. While the surveillance system is passive and likely underestimates true incidence, data reveal an increase in SFGR infection rates. The Council of State and Territorial Epidemiologists classifies cases through clinical and laboratory criteria. Clinical criteria include a reported fever and at least one symptom such as a rash, eschar or headache [4]. Laboratory criteria differentiate between laboratory confirmed cases and laboratory supportive cases.

Two changes in surveillance definition occurred during 2004–2013. Beginning in 2004, the RMSF

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case definition incorporated newer laboratory techniques such as PCR. Cases were considered laboratory confirmed if diagnosed with paired IFA titres, IHC, PCR or cell culture. In 2008, the surveillance case definition was expanded to include laboratory supportive cases to better reflect clinical practices. While the definition for laboratory confirmed cases remained unchanged, laboratory supported cases were those that were diagnosed with a single IgG or IgM titre by IFA, ELISA, or a latex agglutination test [4]. Then, in 2010, RMSF was combined with other SFGR for surveillance because most diagnostic tests cannot reliably differentiate between RMSF and other SFGR such as *R. parkeri* and *Rickettsia* species 364D [5].

Prior studies have found correlations between climate variables and tick populations [6–9]. Tick abundance has been associated with elevated temperatures [8, 10], cumulative degree-days [6] and precipitation [6, 10]. Climate also affects tick abundance through host distribution and habitat [11]; studies have shown the *D. variabilis* life cycle to be affected by temperature [12], moisture [13] and the distribution of vertebrate hosts [13]. The relationship between climate changes and either the peak [14–16] or average [10] annual onset of tick-borne disease has also been described. Less is known about the local influence of weather variables on the reported incidence of rickettsial diseases. Hermann *et al.* [10] identified a positive association between temperature and RMSF in Illinois, but did not assess a wider array of weather variables. Drought indices and warm winter temperatures have been associated with increased incidence of Lyme disease in some states [17], but were not assessed for SFGR.

Recent studies have attributed the nationwide increase in incidence of SFGR to an increase in less pathogenic rickettsial diseases [1, 18]. These cases may be occurring secondary to expansion of the range of *Amblyomma americanum* ticks, resulting in proportionally fewer cases of RMSF but higher rates of SFGR [18]. The objective of this study was therefore to characterize factors predictive of the annual incidence of SFGR in Illinois, focusing specifically on surveillance and weather.

METHODS

This study was a retrospective analysis of SFGR cases reported to the Illinois Department of Public Health during 2004–2013. These included confirmed and probable reported cases of RMSF from 2004 to 2009 and confirmed and probable reports of SFGR from 2010 to 2013, in accordance with changes in the case definition [4, 5]. Demographic factors included the year and county of disease onset. Clinical factors included the case status and the occurrence of laboratory testing. Cases were examined by county and by the nine climate divisions established by the National Oceanic and Atmospheric Administration [19]. U.S. Census Bureau data were used to calculate incidence rates of SFGR by county and climate division [20, 21].

Weather data were provided by the Illinois State Climatologist's Office, a part of the Illinois State Water Survey (ISWS) (www.isws.illinois.edu/atmos/statecli) and the Midwestern Regional Climate Center, cli-MATE (http://mrcc.isws.illinois.edu/CLIMATE/) [22]. These variables included minimum, maximum and mean annual temperature, mean winter temperature, annual precipitation, mean relative humidity and the Palmer Hydrological Drought Index of each summer month for the current year (t) as well as each of the previous 2 years ($t-1$ and $t-2$, respectively). All variables were reported by county, except for the Drought Index, which was reported by climate division.

The de-identified dataset used for this study did not specify the types of laboratory testing used to make each diagnosis. To evaluate the role played by the changes in surveillance definition in 2008 and 2010, we examined incidence of SFGR over time. An abrupt, sustained increase in incidence following a change in surveillance case definition was considered consistent with an impact of these changes.

Univariate and bivariate analyses of demographic and clinical factors were performed for all reported SFGR cases within Illinois between 2004 and 2013. Fisher's exact tests and χ^2 tests were used to assess case status among each category of variables. Due to the non-normal distribution of SFGR, negative binomial regression was used to determine the associations between weather factors and annual incidence of SFGR by climate division. A final model of SFGR incidence as a function of weather variables was created with stepwise modelling for which incidence rate ratios (IRRs) and their 95% confidence intervals (CI) were calculated. Statistical analysis was performed using SAS® version 9·4 (SAS Institute, Cary, NC).

Human Subjects Protection: This work was determined to not constitute human subjects research by the University of Illinois at Chicago Institutional Review Board.

RESULTS

A total of 590 cases of SFGR were reported in Illinois between 2004 and 2013, with more than half ($n = 396$) occurring in climate divisions 8 and 9, the two southernmost climate divisions of the state (Fig. 1). Estimated annual incidence of SFGR varied by climate division within Illinois and ranged from 0 to 300 cases per million persons (Table 1). Marked increases in cases occurred in 2008, 2012 and 2013 (Table 1). The increases in 2012 and 2013, statewide and in the two southernmost climate divisions, coincided with warm winter temperatures (Fig. 2*a*, *b*). Only 3·4% of reported cases of SFGR in Illinois were confirmed (Table 2). The percentage of confirmed cases varied significantly by climate region, with relatively low proportions of confirmed cases in areas with higher incidence (1·6% and 4·2% confirmed cases in Regions 8 and 9, respectively, *vs.* 16·7% confirmed in Region 4).

Associations were observed between temperature and precipitation variables and increased incidence of SFGR (Table 3). A 0·56 °C (1°F) elevation in mean winter temperature was associated with a 32% increase in incidence of SFGR (IRR 1·32, CI 1·25–1·40), whereas a 2·54 cm (1 inch) increase in annual precipitation was associated with an 8% increase in incidence (IRR 1·08, CI 1·04–1·11). No association between relative humidity or Palmer Hydrological Drought Index values and SFGR incidence was found.

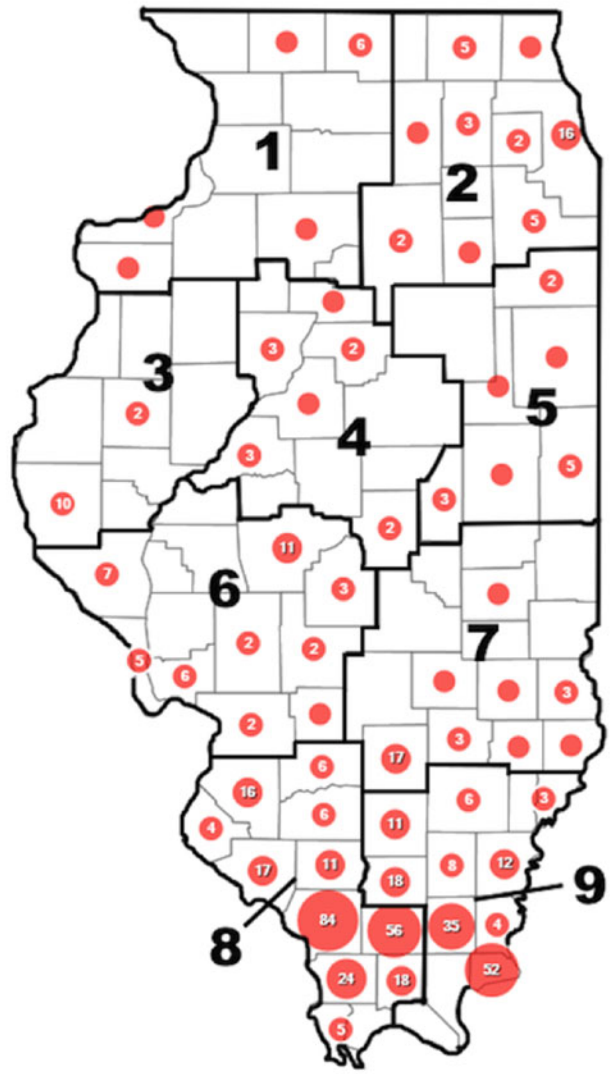

Fig. 1. Distribution of SFGR cases in Illinois, 2004–2013, by county and climate division ($n = 590$). Six contiguous southern counties accounted for nearly 46% ($n = 269$) of all reported cases: Jackson, Williamson, Saline, Gallatin, Union and Johnson.

CONCLUSIONS

The estimated annual incidence of SFGR was relatively constant statewide from 2004 to 2013; however, incidence rates spiked in 2008 and again in 2012–2013 especially in the southern regions of Illinois. From 2004 to 2012, the reported incidence of SFGR in Illinois increased more than 11 times, from less than one case per million persons in 2004 to over 11 cases per million persons in 2012. In contrast, the national SFGR incidence increased 7-fold from 2000 to 2012 [1]. A recent study suggests that this elevation in incidence rate is secondary to the increasing range of the *A. americanum* tick that transmits *Rickettsia amblyomii* [18]. However, these findings best explain the increase in SFGR over the past two decades; and they do not explain the variation in incidence rates seen from year to year. In Illinois, our data showed that the incidence rates spiked in both 2008 and 2012, trends that were mirrored nationally [1].

In prior studies, surveillance changes were found to affect variation in yearly incidence. For example, Openshaw *et al.* pointed to changes in case definition as a cause of elevated national SFGR incidence rates between 2000 and 2008 [23]. While a change in case definition occurred concurrently with a spike in Illinois incidence in 2008, no sustained increase in cases was noted. From 2009 to 2011, a dramatic decrease in reported cases was seen; this indicates that the increased incidence in 2008 was less likely to be a result of the case definition change in that year. The 2008 change in RMSF case definition expanded the number of reported cases by incorporating additional laboratory tests into the probable case

Table 1. *Incidence rate of SFGR per million persons by year and climate division in IL, 2004–2013*

	Climate division								
Year	1	2	3	4	5	6	7	8	9
2004	1·29	0·12	0	0	2·09	0	3·03	8·80	25·63
2005	0	0·12	0	0	0	1·42	0	8·77	20·52
2006	2·57	0·46	0	0	0	1·42	6·06	19·16	30·90
2007	2·55	0·23	4·01	1·38	4·08	7·07	3·03	33·01	30·98
2008	1·27	0·23	4·03	0	2·03	1·41	18·20	69·21	300·42
2009	0	0·34	12·09	4·09	2·02	4·23	0	44·80	52·10
2010	0	0·68	4·03	4·09	2·02	7·04	3·04	22·29	36·46
2011	0	0·11	8·07	0	0	9·86	21·33	37·74	62·67
2012	2·58	1·13	12·16	5·43	10·08	16·95	18·34	106·73	246·47
2013	2·59	0·68	4·07	1·35	4·03	5·67	12·27	76·05	200·18

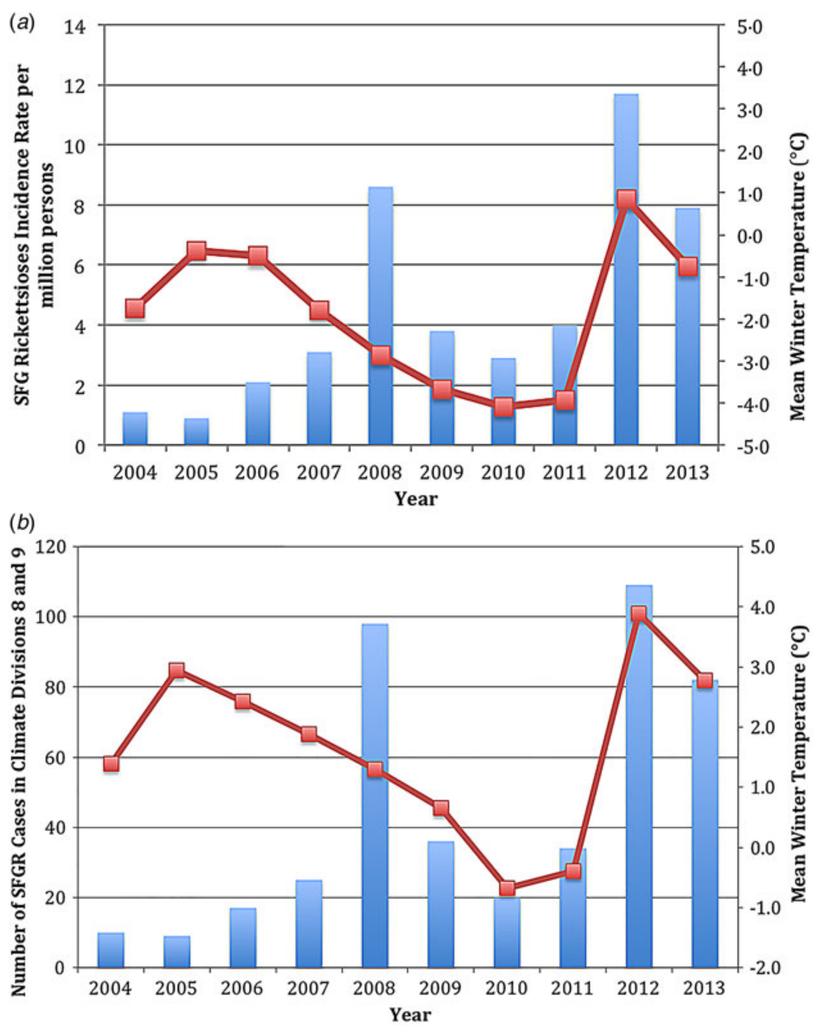

Fig. 2. (*a*) Incidence rate of SFGR in Illinois between 2004 and 2013 and mean winter temperature (°C) by year of study. The blue bars represent annual incidence of SFGR in Illinois per million persons. The red line represents mean winter temperature in degrees Celsius. (*b*) The number of cases of SFGR and the mean winter temperature (°C) within climate divisions 8 and 9 in Illinois between 2004 and 2013. The blue bars represent total number of SFGR cases in climate divisions 8 and 9. The red line represents mean winter temperature in degrees Celsius in climate divisions 8 and 9.

Table 2. *Distribution of SFGR cases (n = 590) and prevalence of confirmed cases in IL, 2004–2013*

Characteristic	*N* (% of sample)	% Confirmed
Status		
Confirmed	20 (3·4)	–
Probable	570 (96·6)	–
Climate division		
1	10 (1·7)	10·0
2	36 (6·1)	8·3
3	12 (2·0)	0·0
4	12 (2·0)	16·7
5	13 (2·2)	15·4
6	39 (6·6)	0·0
7	28 (4·8)	0·0
8	247 (41·9)	1·6
9	193 (32·7)	4·2
Year		
2004	14 (2·4)	7·1
2005	11 (1·9)	0·0
2006	26 (4·4)	0·0
2007	39 (6·6)	0·0
2008	110 (18·6)	2·7
2009	49 (8·3)	2·0
2010	37 (6·3)	8·1
2011	51 (8·6)	0·0
2012	151 (25·6)	6·0
2013	102 (17·3)	2·9

Table 3. *Incidence rate ratios of SFGR in IL, 2004–2013 by individual and multivariable climate data*

	IRR (95% CI)
Individual variables	
Min temp (°F)	1·67 (1·44–1·92)
Mean temp (°F)	1·55 (1·35–1·79)
Max temp (°F)	1·44 (1·25–1·66)
Winter temp (°F)	1·32 (1·24–1·41)
Precipitation (in.)	1·05 (1·01–1·10)
Relative humidity (%)	0·82 (0·70–0·96)
June PHDI (*t*)	0·97 (0·84–1·12)
June PHDI (*t* – 1)	1·04 (0·90–1·20)
June PHDI (*t* – 2)	1·10 (0·88–1·36)
July PHDI (*t*)	0·97 (0·86–1·10)
July PHDI (*t* – 1)	0·99 (0·87–1·14)
July PHDI (*t* – 2)	1·14 (0·91–1·42)
August PHDI (*t*)	0·94 (0·82–1·07)
August PHDI (*t* – 1)	0·90 (0·78–1·03)
August PHDI (*t* – 2)	0·96 (0·79–1·18)
Multivariable model	
Winter Temp (°F)	1·32 (1·25–1·40)
Precipitation (in.)	1·08 (1·04–1·11)

PHDI, Palmer Hydrological Drought Index; measure of groundwater levels indicative of cumulative drought conditions; *t*, current year measure; *t* – 1, prior year measure; *t* – 2, 2 years prior measure.

definition. This change was reflective of clinical practices that were already occurring. Therefore, it would be expected that if the increase in cases occurred secondary to the case definition change, then the increase would be sustained in the following years. Another explanation for the spike in incidence in Illinois may be the occurrence of a fatal case of RMSF in southern Illinois that year [24]. Publicity of this case may have increased physician and public awareness of RMSF, leading to increased testing and more positive cases.

In contrast to 2008, increases in 2012 and 2013 were not temporally associated with changes in case definition. Although the case definition was expanded in 2010 to include all SFGR [5], we suspect that this change did not significantly contribute to increasing incidence given the relatively low incidence rates in 2010 and 2011. In both 2012 and 2013, however, the winter temperatures were unusually warm (Fig. 2*a*, *b*), supporting the observed statistical association between warmer winter weather and elevated incidence of SFGR. Furthermore, much of the increase in incidence was seen in climate divisions 8 and 9 (Table 1). These two climate regions represent the southernmost portion of Illinois and had the warmest winters and overall temperatures in the state.

Another recent Illinois study also found correlations between increased prevalence of RMSF and both higher annual temperature and precipitation [10], but to our knowledge ours is the first to specifically examine winter temperature. Warmer conditions lead to earlier egg hatching [12] and higher adult tick activity allowing greater potential for transmission [25]. Additionally, warmer winters lead to increased soil temperature and an earlier end to overwintering, which may allow the presence of a second summer adult cohort [7]. Warmer conditions also may lead to increased activity of small mammal hosts on which *Dermacentor* larvae and nymphs feed, potentially increasing tick distribution [13]. These additional adult ticks and the higher levels of dog and human activity in warmer weather may lead to increased opportunities for transmission. As the climate continues to warm, public health departments and clinicians should anticipate an increasing number of SFGR cases.

Another interesting finding of our study was the relatively low number of confirmed cases in Illinois. Between 2004 and 2013, only about 3% of cases of

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SFGR in Illinois were confirmed cases compared with 7% of cases confirmed nationally between 2008 and 2012 [18]. This may be in part due to reporting errors, as laboratory testing was reported as either not performed or unknown in 22 cases (3·7%) despite the testing component of the case definition. Given the low confirmation rates of cases in areas with high numbers of cases (Table 2), it is possible that clinicians may be prioritizing treatment of suspected SFGR and deemphasizing surveillance case confirmation. This may be due to the additional cost and difficulty of having patients return for a second blood draw, especially in regions where RMSF is relatively common and physicians feel confident in their diagnosis. RMSF, the most common SFGR, is considered among the most severe tick-borne diseases, with marked reduction in fatality rates of RMSF among those diagnosed and treated early. Although immediate treatment has obvious importance, failure to confirm the diagnosis has negative implications for surveillance. Accurate surveillance can lead to dissemination of important epidemiological data to clinicians in high-incidence areas. Additionally, enhanced awareness of the surveillance case definition may allow more representative and complete reporting, therefore allowing a more accurate assessment of the burden of disease. This can then lead to enhanced prevention through the development of education programs aimed at both practitioners and the general public.

Our study has several limitations. First, the data reported were passive surveillance data and thus subject to under-reporting. Additionally, in the dataset available for analysis, cases were reported on an annual and not a monthly basis so temporal associations between weather and incidence could not be made. Data on the type of laboratory testing performed for each case were also not available; therefore, we could not assess for correlations between method of laboratory testing and incidence. Our study did not assess soil or vegetation factors that can impact disease incidence by affecting tick populations. Finally, tick data were unavailable for this time period throughout Illinois. Our findings would be strengthened by correlating changes in tick populations with variations in weather over time.

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DISCLAIMERS

This work does not necessarily reflect the views of CDC or the Illinois Department of Public Health.

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