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The epidemiology of human salmonellosis in New Zealand, 1997–2008

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SUMMARY

This study describes the epidemiology of human salmonellosis in New Zealand using notified, hospitalized and fatal cases over a 12-year period (1997–2008). The average annual incidence for notifications was 42·8/100 000 population and 3·6/100 000 population for hospitalizations. Incidence was about twice as high in summer as in winter. Rural areas had higher rates than urban areas (rate ratio 1·23, 95% confidence interval 1·22–1·24 for notifications) and a distinct spring peak. Incidence was highest in the 0–4 years age group (154·2 notifications/100 000 and 11·3 hospitalizations/100 000). Hospitalizations showed higher rates for Māori and Pacific Island populations compared to Europeans, and those living in more deprived areas, whereas notifications showed the reverse, implying that notifications are influenced by health-seeking behaviours. *Salmonella* Typhimurium was the dominant serotype followed by *S.* Enteritidis. For a developed country, salmonellosis rates in New Zealand have remained consistently high suggesting more work is needed to investigate, control and prevent this disease.

Key words: Epidemiology, public health emerging infections, salmonellosis, zoonoses.

INTRODUCTION

Salmonellosis is a significant public health concern, being a leading cause of human enteric illness worldwide, with higher rates in immunocompromised populations [1]. Large-scale ecological changes, particularly climate and land-use modifications, may have a considerable effect on salmonellosis distribution by influencing pathogen biology, environmental reservoirs, transmission pathways, and host–pathogen interactions [2]. Hot, humid conditions and lagged temperature have been positively associated with gastroenteritis [3] and salmonellosis incidence in Australia [4]. In New Zealand, a 1 °C increase in monthly average temperature is estimated to result in a 15% increase in reported salmonellosis [5]. Increasing evidence of zoonotic transmission from farmed animals [6] and wildlife [7], and subsequent contamination of waterways [8] and drinking water supplies [9] suggest that land use is an important determinant of salmonellosis in New Zealand.

Describing the relative contribution of specific serotypes can assist in prioritization of populations vulnerable to environmental change. The distribution of *Salmonella* serotypes in the environment can vary temporally [10] and with different socioeconomic and

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demographic groups [11]. As serotypes can have distinct epidemiologies, it has been suggested that identifying pathogenic serotypes of *Salmonella* could help determine their differential public health impact and specific environmental risk factors [12].

New Zealand has relatively high rates of salmonellosis compared to other industrialized countries [5]. This disease accounts for 7·35% of total disability adjusted life years attributed to major foodborne diseases (ranking fourth in impact after campylobacteriosis, norovirus and perinatal listeriosis) [13]. Despite its importance, there have been few comprehensive reports on salmonellosis epidemiology in New Zealand [14]. In this study we used multiple surveillance sources, particularly notifications, hospitalizations and serotype prevalence data, to describe epidemiological patterns in salmonellosis in New Zealand over a 12-year period 1997–2008.

METHODS

Data sources

All notified cases of salmonellosis during 1997–2008 in New Zealand were obtained from the National Notifiable Disease Surveillance system (EpiSurv) which is operated by the Institute of Environmental Science and Research (ESR) for the NZ Ministry of Health. Hospital and mortality data for the same period were obtained from the National Minimum Dataset managed by the Ministry of Health. Population denominator data, including age, sex, ethnicity and Census Area Unit (CAU code), were based on the 2001 National Census of Population and were obtained from Statistics New Zealand. A CAU is a non-administrative, geographical unit defined by Statistics New Zealand, each of which comprises a population of 3000–5000 people. Tabulated data on *Salmonella* isolates were obtained from ESR.

For notifications, cases were defined as a clinical illness with appropriate laboratory confirmation. For hospitalizations, we used all discharged cases with a principal diagnosis of salmonella infection (ICD-9-CM code 003 and ICD-10-AM code A02). The analysis was restricted to overnight or longer admissions and New Zealand residents. In order to include only incident cases, if the same individual was re-admitted with the identical diagnosis within 30 days, only the first record was included. For mortality records we used those where the underlying cause of death was coded as *Salmonella* infection.

Exposure variables

Based on date of notification and hospitalization, cases were assigned to Southern Hemisphere seasons as follows: summer (December–February), autumn (March–May), winter (June–August) and spring (September–November).

Cases were assigned to one of the seven categories of rurality based on population number and employment status as defined by Statistics New Zealand [15]. These categories are: main urban areas, satellite urban areas, independent urban areas, rural areas with high urban influence, rural areas with moderate urban influence, rural areas with low urban influence, and highly rural/remote areas. Average monthly rates for urban and rural areas were calculated by classifying the first three categories as urban and the latter four as rural.

The deprivation index, an area based index, derived from variables important to social and material deprivation [16] was used as a socioeconomic level indicator. It is constructed on a decile scale with deprivation level 1 representing socioeconomically affluent CAUs and level 10 representing the most deprived CAUs. In this study, deprivation levels were grouped into five quintiles. Ethnicity was based on level 1 prioritized ethnicity which divides the population into Māori, Pacific, Asian, European and Other.

Analysis

Rates were calculated using the 2001 Population Census and converted to average rates per 100 000 population per year (hereafter referred to as average annual rates or rates per 100 000 population). Ninety-five percent confidence intervals (CIs) were reported based on average annual rates for the duration of the study period. Rates for ethnic groups were directly age-standardized to the age distribution of the national population in 2001; 95% CIs were calculated based on the age-standardized rates. ArcGIS v. 10 was used for mapping.

RESULTS

Incidence time trends and seasonality

The incidence of salmonellosis notifications, hospitalizations and fatalities was used to assess the public health impact of this disease in New Zealand. The average annual rate of salmonellosis notifications was

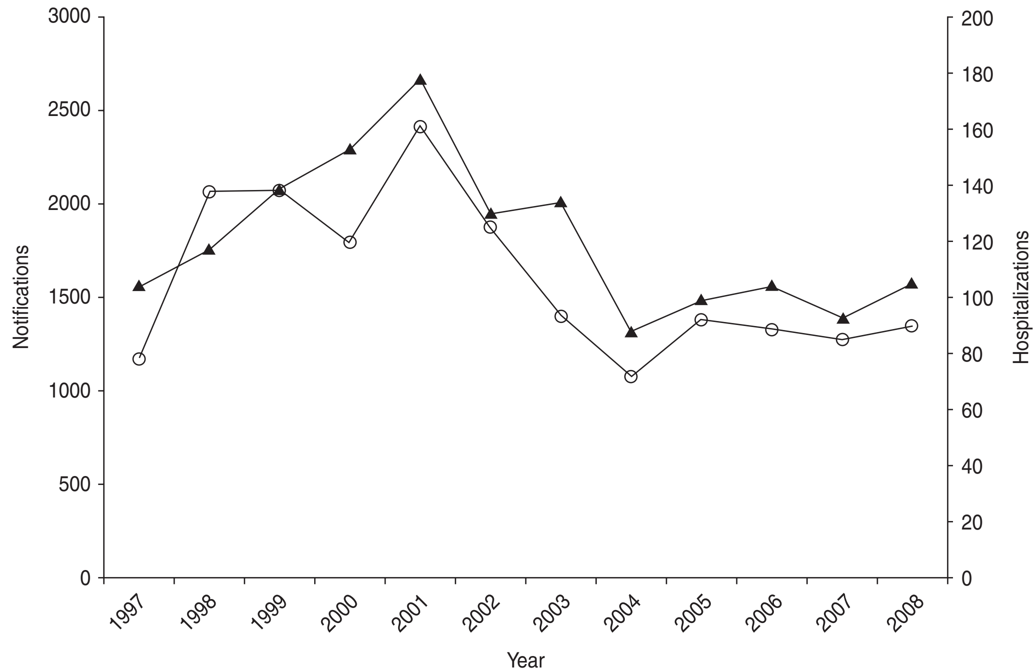

Fig. 1. Number of salmonellosis notifications (–○–) and hospitalizations (–▲–) in New Zealand, 1997–2008.

42·8 cases/100 000 population, hospitalizations were 3·6 cases/100 000 population, and mortality was 0·02 cases/100 000 population (based on an average of 1603 notifications, 135 hospitalizations and 3·3 deaths per year over that period).

Salmonellosis notification and hospitalization rates showed a similar temporal pattern to each other over the 12-year period 1997 to 2008 (Fig. 1). Incidence rose to a peak in 2001 with 2417 notified cases and 178 hospitalizations then declined to a level broadly similar to that at the start of the observation period.

Both notification and hospitalization rates peaked in summer with average annual incidences of 14·4/100 000 and 1·3/100 000 population, respectively, with rates dropping to about half that level over winter (Table 1). Seasonality showed a different pattern in rural areas with a marked spring peak (6·4/100 000 population) that was absent in urban populations which only experienced a single peak in summer (4·9/100 000 population) (Fig. 2).

Geographical distribution and urban–rural differences

Average annual salmonellosis incidence rates by Territorial Authority (TA) (geographical aggregations of CAUs) for both notifications and hospitalizations are shown in Figure 3. Notification and hospitalization rates were consistently above the national average in the South Island TAs particularly towards the lower end of the South Island (Ashburton, Southland, Clutha, Gore). North Island TAs with large rural regions also had high rates (Wairarapa, Carterton). Average annual notification rates were highest in Clutha (109·6/100 000), followed by Southland (105·6/100 000) (Fig. 3). Average annual hospitalization rates were highest in Ashburton (10·4/100 000) followed by Gore (10·0/100 000).

Salmonellosis rates were generally higher in rural areas compared to urban areas (Table 1). Overall, average annual notification rates in urban areas were 41·2/100 000 population compared to 51·0/100 000 population in rural areas [rate ratio (RR) 1·23, 95% CI 1·22–1·24]. There was a similar gradient for hospitalization rates, with average rates in urban areas of 3·3/100 000 population compared to 4·0/100 000 population in rural areas (RR 1·20, 95% CI 1·19–1·22). For both notification and hospitalization rates, there appeared to be a tendency for increasing incidence rates with increasing grade of rurality (Table 1) with rates in remote areas exceeding those in any other category for hospitalizations (5·4/100 000 population). Rates in rural areas with high urban influence had the highest rates for notifications (59·9/100 000 population).

Age, sex, ethnicity and deprivation

Average annual salmonellosis notification and hospitalization rates varied by age (Table 1). For notified

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Table 1. *Numbers and rates* (*average per 100 000 population per year*) *of salmonellosis notifications and hospitalization by season, rural–urban domicile, age group, sex, ethnicity, and deprivation level, New Zealand, 1997–2008*

	Salmonellosis notifications			Salmonellosis hospitalizations		
Category	No.	Rate*	RR (95% CI)†	No.	Rate	RR (95% CI)
Season						
Summer	6469	14·42	**1**	596	1·32	**1**
Autumn	4348	9·69	0·67 (0·66–0·67)	323	0·72	0·54 (0·51–0·57)
Winter	3647	8·13	0·56 (0·55–0·57)	285	0·63	0·48 (0·45–0·51)
Spring	4770	10·63	0·73 (0·73–0·74)	420	0·93	0·70 (0·68–0·72)
Urban/rural						
Main urban	13 680	42·93	**1**	965	3·02	**1**
Satellite urban	519	38·96	0·90 (0·90–0·91)	60	4·50	1·49 (1·30–1·67)
Independent urban	1668	31·77	0·74 (0·73–0·74)	269	5·12	1·69 (1·55–1·83)
Rural, high urban	762	59·90	1·39 (1·35–1·43)	37	2·90	0·96 (0·95–0·97)
Rural, moderate urban	773	54·53	1·27 (1·24–1·29)	45	3·17	1·05 (1·03–1·06)
Rural, low urban	1377	45·46	1·05 (1·05–1·06)	141	4·65	1·54 (1·40–1·67)
Highly rural/remote	347	52·23	1·21 (1·18–1·24)	36	5·41	1·79 (1·32–2·26)
Age group (yr)						
0–4	5009	154·25	5·11 (4·53–5·69)	368	11·33	5·75 (2·95–8·54)
5–9	1601	46·64	1·54 (1·50–1·58)	105	3·05	1·55 (1·38–1·71)
10–19	2065	30·97	1·02 (1·02–1·02)	186	2·78	1·41 (1·33–1·50)
20–29	2771	47·51	1·57 (1·54–1·60)	205	3·51	1·78 (1·59–1·97)
30–39	2265	32·76	1·08 (1·08–1·09)	177	2·56	1·29 (1·24–1·35)
40–49	1942	30·15	**1**	127	1·97	**1**
50–59	1491	29·73	0·98 (0·98–0·98)	144	2·87	1·45 (1·34–1·56)
60–69	987	29·14	0·96 (0·96–0·96)	138	4·07	2·06 (1·69–2·43)
70–79	574	22·49	0·74 (0·73–0·76)	125	4·89	2·48 (1·83–3·13)
⩾80	238	18·09	0·60 (0·56–0·63)	49	3·72	1·89 (1·41–2·36)
Sex						
Male	9910	45·36	**1**	808	4·03	**1**
Female	9033	39·35	0·86 (0·86–0·86)	816	4·03	1·00 (1·00–1·00)
Ethnicity‡						
European	13 193	42·14	**1**	1069	3·41	**1**
Māori	1521	23·47	0·55 (0·54–0·56)	282	5·69	1·66 (1·55–1·78)
Pacific	513	21·85	0·51 (0·49–0·53)	118	6·35	1·86 (1·60–2·11)
Asian	592	15·53	0·36 (0·34–0·39)	52	1·66	0·48 (0·41–0·55)
Other	105	25·33	0·60 (0·54–0·65)	5	1·07	0·31 (0·07–0·56)
Deprivation level						
1–2	3339	37·25	**1**	217	2·64	**1**
3–4	2905	33·05	0·88 (0·88–0·89)	270	3·35	1·26 (1·22–1·31)
5–6	2671	31·29	0·84 (0·83–0·84)	310	3·96	1·50 (1·41–1·58)
7–8	2433	29·13	0·78 (0·77–0·78)	365	4·76	1·80 (1·65–1·95)
9–10	2108	25·20	0·67 (0·66–0·68)	439	5·72	2·16 (1·93–2·40)
Total	19 234	42·88	n.a.	1624	3·62	n.a.

RR, Rate ratio; CI, confidence interval; n.a., not applicable.

* Rate is the average annual rate per 100 000 population.

† RR is calculated in reference to the value in bold; 95% CI is calculated based on the whole period.

‡ Rates for ethnic groups were directly age-standardized to the age distribution of the New Zealand population at the 2001 Census. 95% CI were calculated based on methods for age standardization.

cases, the highest incidence was detected in children aged 0–4 years (154·2/100 000 population), followed by adults in the 20–29 years age group (47·5/100 000 population), while the lowest incidence was in the ⩾80 years age group (18·0/100 000 population) (Table 1). Males (45·3/100 000 population) had a

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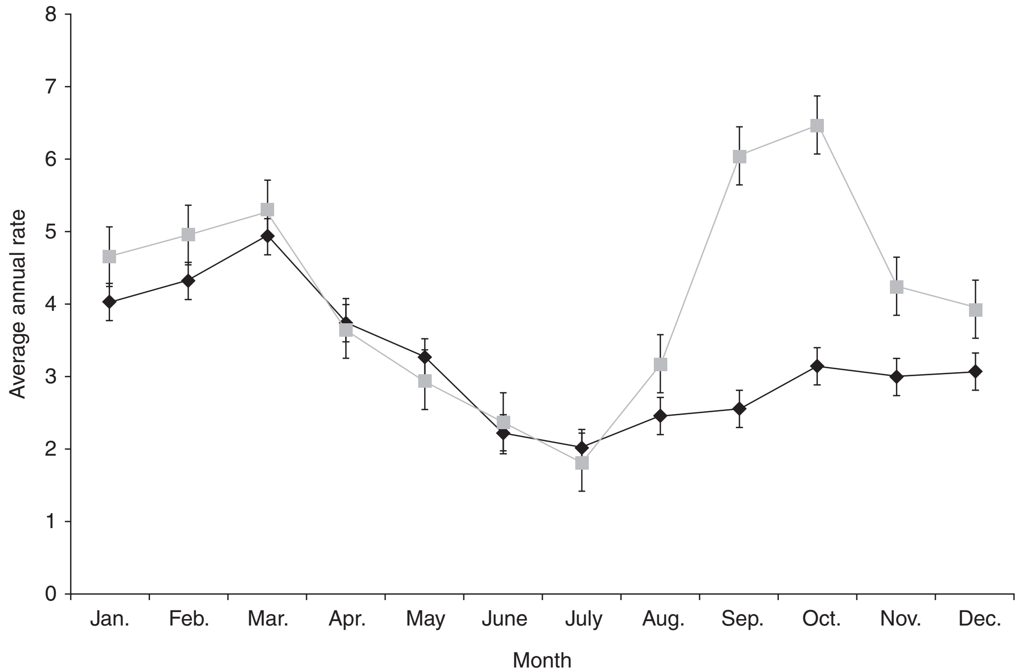

Fig. 2. Average annual, monthly rate of salmonellosis notifications by urban (—◆—) and rural (—■—) status, 1997–2008. Standard error bars are shown.

slightly higher average incidence rates than females (39·3/100 000 population). Hospitalization rates were also highest in children aged 0–4 years (11·3/100 000 population), but unlike notification rates had a second peak in older adults aged 70–79 years (4·8/100 000 population). Unlike notification rates, hospitalization rates showed no differences between sexes.

Average annual incidence rates varied by ethnicity but patterns were very different for notifications and hospitalizations (Table 2). For notifications, Europeans had the highest age-standardized rates (42·1/100 000 population), with lower rates for Māori (23·4/100 000 population), Pacific Island (21·8/100 000 population) populations, Asian (15·5/100 000 population), and 'Other' ethnic groups (25·3/100 000 population). However, this pattern was largely reversed for hospitalized cases. The Pacific Island (6·3/100 000 population) and Māori (5·6/100 000 population) people had the highest rates, with Europeans (3·4/100 000 population) recording the third lowest incidence rate among ethnic groups followed by Asians (1·6/100 000 population) and 'Other' (1·0/100 000 population).

Salmonellosis also varied by level of deprivation, again with contrasting patterns for notification and hospitalization rates (Table 1). Average annual notification rates in the least deprived CAUs were higher (37·2/100 000 population) compared to the most deprived CAUs (25·20/100 000 population). Hospitalization rates were reversed with higher rates recorded for the most deprived CAUs (5·7/100 000 population) compared with the most affluent CAUs (2·6/100 000 population).

Salmonella serotypes

The predominant *Salmonella* serotype in New Zealand is *S.* Typhimurium (accounting for 64% of all strains isolated over the 1997–2008 period) followed by *S.* Enteritidis (~10%) (Table 2). The marked rise in *Salmonella* incidence (as measured by notification and hospitalization rates) during the period 1998–2003 was driven largely by a rise in *S.* Typhimurium particularly DT135, DT1, DT101, DT156, DT160 and by *S.* Brandenburg.

DISCUSSION

This is the first study to describe national patterns in salmonellosis notifications and hospitalizations in New Zealand. Salmonellosis incidence continues to be high, with a period of multiple overlapping *Salmonella* outbreaks that further increased incidence from 1997 to 2008. These findings demonstrate marked ethnic and socioeconomic inequalities in disease distribution, with higher hospitalization rates for

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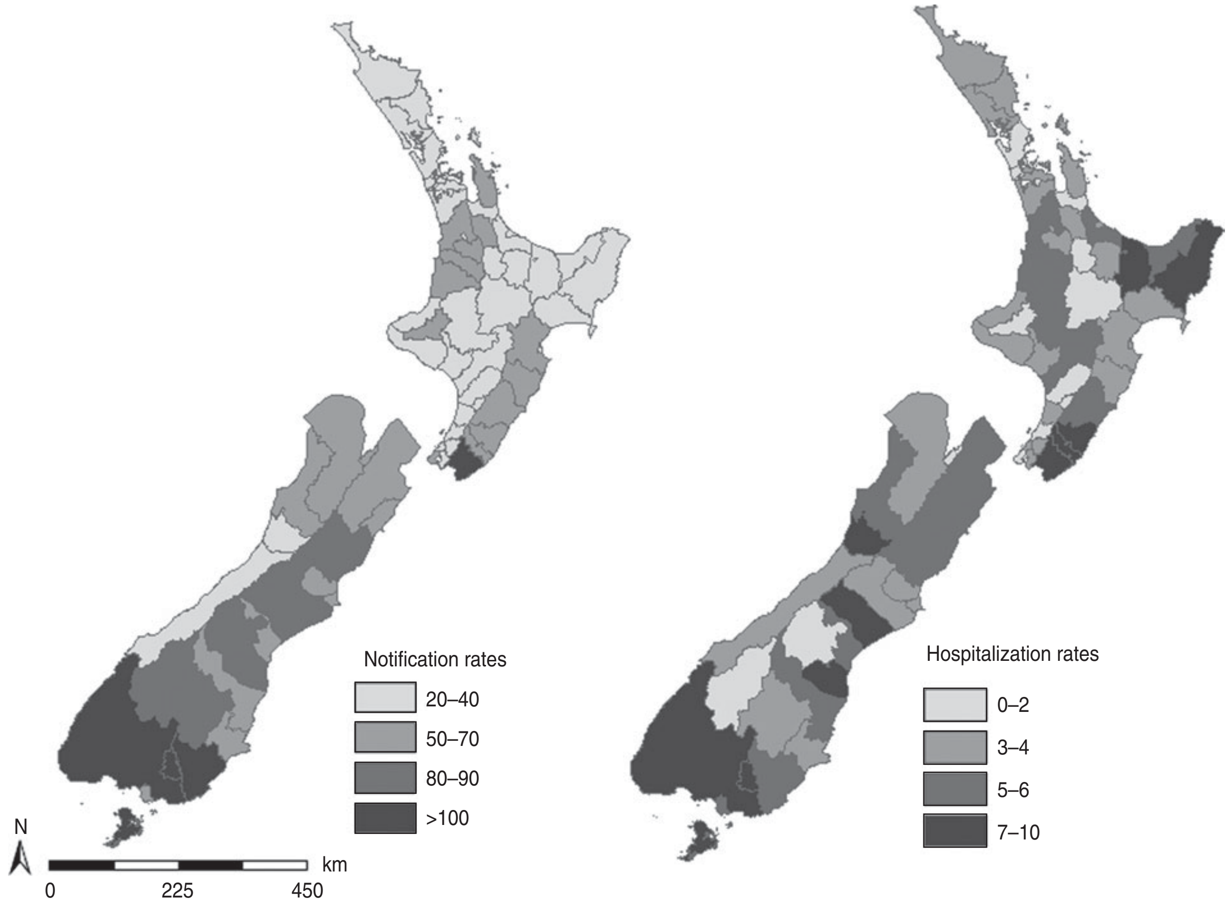

Fig. 3. Salmonellosis notification and hospitalization rates (average per 100 000 population per year) by Territorial Authority, New Zealand, 1997–2008.

Māori and Pacific peoples and those living in more deprived neighbourhoods. Results also suggest a different epidemiology in rural areas which experience higher overall rates and a spring peak that is absent in urban populations.

The reported incidence of salmonellosis in New Zealand is relatively high by international standards. Rates in comparable countries are 35·8/100 000 (Australia) [17], 9·9/100 000 (USA) [14] and 25·9/100 000 (Canada) [18]. The summer peak in salmonellosis incidence is similar to that previously reported [19]. It is hypothesized to be partly due to favourable ambient environmental conditions for pathogen survival [20], seasonal variations in pathogen reservoirs [6], transmission pathways [10] and host behaviour [21]. Positive associations between temperature and salmonellosis incidence in countries across Europe [20] and Australia [4] have been documented. In New Zealand, Britton *et al.* [5] estimated a 15% increase in notifications for every 1 °C rise in average monthly temperature. This has important implications in New Zealand as temperatures are projected to rise by 2 °C by 2090 relative to levels in 1900 [22].

Studies have also reported a positive association between seasonal rainfall and *Salmonella* occurrence [10]. Climate change projections for New Zealand include an increase in rainfall in western and southern areas, with increased frequency of heavy precipitation events in the west [22]. Consequently, regional climatic differences could contribute to disproportionately adverse health outcomes for some populations.

Our study indicated relatively high notification and hospitalization rates in spring (September–November). Spring rates were strongly influenced by rural populations which experienced a dominant spring peak in addition to one in summer, unlike urban populations which have a single peak in summer. This difference probably reflects greater local exposures to environmental pathogen reservoirs and opportunities for pathogen–human contact due to seasonal host activities. A study in Scotland reported

Table 2. *Total number of selected* Salmonella *serotypes from laboratory-confirmed salmonellosis notifications, 1997–2008*

	Year											
Serotype	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
S. Typhimurium												
DT160	—	—	4	169	791	561	334	221	248	260	152	135
DT42	—	—	—	—	—	—	—	—	27	28	15	93
DT101	62	258	131	112	77	44	66	31	67	71	43	72
DT1	95	201	174	123	171	225	110	65	114	72	91	72
DT156	99	149	151	91	111	85	95	56	75	87	73	67
DT135	114	296	459	370	264	155	68	30	—	—	—	—
DT74	—	—	—	—	—	—	—	—	28	42	29	21
Other	282	388	287	260	252	197	280	177	198	173	193	269
Total	652	1292	1206	1125	1666	1267	953	580	757	733	596	729
S. Enteritidis												
PT9a	66	83	106	65	73	88	65	44	73	53	60	45
PT4	51	49	54	42	24	41	22	11	—	—	—	—
PT1b	—	—	—	—	—	—	—	—	9	9	18	19
PT26	—	—	—	—	—	—	—	—	9	7	17	10
Other	24	32	27	20	73	43	50	87	60	38	56	50
Total	141	164	187	127	170	172	137	142	151	107	151	124
S. Infantis	29	21	71	32	73	94	89	63	67	58	86	86
S. Chester	—	—	—	—	—	—	—	—	0	1	37	64
S. Mbandaka	—	—	—	—	—	—	—	—	8	22	14	39
S. Saintpaul	33	32	31	21	16	35	27	33	65	35	25	35
S. Brandenburg	35	156	149	165	17	85	55	86	68	55	47	33
S. Thompson	3	2	5	8	16	25	10	22	—	—	—	—
S. Montevideo	5	13	6	14	5	21	37	8	—	—	—	—
S. Heidelberg	2	6	5	3	127	15	11	3	—	—	—	—
Other/Unknown	192	261	268	196	395	353	282	599	274	319	277	215
Total	1093	1948	1932	1698	2605	2607	1601	1164	1406	1343	1267	1339

a spring peak in human salmonellosis cases, with pronounced infection rates in the farming community, compared to higher rates in late summer-early autumn in the general community [23]. In New Zealand, *S.* Brandenburg, associated with the lambing season has been implicated in spring peaks in rural cases in southern New Zealand [24].

Results show that salmonellosis risk is significantly higher in rural areas, although the relationship with increasing degree of rurality is not linear. Analogous to other, enteric zoonotic pathogens such as *Campylobacter* and verocytotoxigenic *Escherichia coli* (VTEC) factors such as a high number of livestock [25], activities involving contact with contaminated surface water [26] and private water supplies [27] have been associated with increased disease rates in rural areas. In New Zealand, an association between peak salmonellosis rates in humans and farming practices [24] and occupational contact with livestock [28] has been reported. Thus, common environmental exposures related to rural living and agricultural activity may be important determinants of salmonellosis incidence in New Zealand and warrant further research.

Consistent with published studies, strong age associations in disease incidence were identified. For both notifications and hospitalizations, the 0–4 years age group had the highest rates. This vulnerability could be a result of increased contact with infection sources [29], susceptibility to infection due to inadequate immunity or a greater probability of seeking treatment [30].

There is less comparable literature on ethnic and socioeconomic patterns in salmonellosis infections. Interestingly, the notification and hospitalization data presented here show opposite patterns with regard to ethnicity and deprivation. Notification rates for Europeans were the highest, while hospitalization rates were highest for Pacific and Māori populations.

A similar reversal is shown for socioeconomic deprivation; while notification rates showed that the socioeconomically advantaged had the highest rates, hospitalization rates indicated the reverse. Other enteric illnesses in New Zealand such as cryptosporidiosis and giardiasis show similar patterns in notification data [31] with only one other study reporting similar patterns in ethnic differences between notifications and hospitalizations [32]. In that study, the authors advocate that such inconsistent patterns could be due to poorer access to health resources resulting in lower rates of reported cases [32]. Higher rates for certain ethnic groups could also indicate cultural differences relating to food preparation and handling, apparently unrelated to deprivation status [33]. Our results highlight the importance of using multiple data sources to describe disease patterns as demographic disparities could be masked when using single sources.

The predominant *Salmonella* serotype in New Zealand is *S.* Typhimurium (accounting for 64% of all strains isolated over the 1997–2008 period) followed by *S.* Enteritidis (~10%). This is similar to patterns reported in Canada [34] and the USA [35]. *S.* Typhimurium has been most commonly reported from urban areas in Canada and The Netherlands [36, 37], suggesting that associated risk factors such as contaminated food of animal origin [38] and sandboxes [29] may be important sources of infection. In contrast, in New Zealand *Salmonella* Typhimurium DT160 is the most frequently isolated [39], with hosts including humans, livestock and wild avian species [40]. Moreover, while the number of *S.* Brandenburg infections remains low nationally, region specific rates have shown an increasing trend [24], tracking changes in environmental reservoirs [6]. Indeed, novel epidemics due to serovar DT160 and *S.* Brandenburg have been reported in New Zealand [40]. Future research into *Salmonella* serotypes based on location characteristics such as urban/rural status, seasonality and known risk factors may be more informative for identifying pathogen reservoirs and formulating explicit prevention and control strategies.

The main limitation of this study is that it was based on passive surveillance data, which is known to suffer from significant underreporting [14] and is of limited value in identifying possible infection sources [31]. However, as in this case, it does indicate areas for future research. Combining data from multiple sources identified some of the systematic biases that affect public health surveillance systems. In particular, notifications which are dependent on access to medical care and use of diagnostics services appear to under-represent Māori and Pacific peoples and more deprived populations. Such biases need to be considered when interpreting and using such data. Finally, different serotypes can be spatially and temporally distinct in their prevalence and transmission, potentially resulting in different patterns of disease incidence [10]. Unfortunately, we were unable to address this in the present study.

Despite these limitations, analysis of aggregated national data can show important patterns in disease incidence. Seasonal patterns indicate that given prospective climate change impacts on health, clarifying the influence of climatic variables on salmonellosis incidence would be helpful. We also reported higher salmonellosis risk in rural areas, particularly in spring with regional increases in zoonotic strains. This has important implications for rural population health in New Zealand as livestock reservoirs are expected to grow. Future work focusing on these seasonal reservoirs and their transmission mechanisms could support disease prevention measures in these populations.

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DECLARATION OF INTEREST

None.

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