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Salmonella enterica serotypes and antibiotic susceptibility in New Zealand, 2002–2007

E. I. BROUGHTON[1]*, H. M. HEFFERNAN[2] AND C. L. COLES[1]

[1] *Johns Hopkins School of Public Health, Department of International Health, Baltimore, MD, USA*
[2] *ESR – Antibiotic Reference Laboratory, Porirua, Wellington, New Zealand*

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SUMMARY

We analysed the serotypes and antibiotic susceptibility of 1560 human and 1505 non-human *Salmonella* isolated in New Zealand (NZ) between 2002 and 2007. The most common serotypes in humans were *Salmonella enterica* serovar Typhimurium, *S.* Enteritidis, *S.* Brandenburg and *S.* Infantis. Over the 6-year period human cases due to *S.* Agona and *S.* Enteritidis increased and cases due to *S.* Typhimurium decreased. The most common serotypes from non-human sources were *S.* Typhimurium, *S.* Brandenberg, *S.* Hindmarsh and *S.* Infantis, and there were no significant changes over time. More isolates were non-susceptible to streptomycin than to any other antibiotic. Almost all isolates were susceptible to ciprofloxacin and gentamicin. There were significant trends of increasing non-susceptibility to streptomycin and sulfonamides in isolates from human and non-human sources, while ampicillin, tetracycline and multidrug non-susceptibility also increased in human isolates. Despite these increases, rates of antibiotic non-susceptibility in *Salmonella* in NZ are still lower than in many international settings.

Key words: Antibiotic resistance, antimicrobial resistance in agricultural settings, public health emerging infections, *Salmonella enterica*, surveillance system.

INTRODUCTION

Non-typhoidal *Salmonella enterica* infection is one of the leading causes of gastrointestinal illness, responsible for several million human cases and thousands of deaths worldwide each year [1]. These Gram-negative zoonotic bacteria are transmitted to humans mostly by exposure to contaminated food. In most cases, the illness is self-limiting and treatment with antibiotics is not recommended. However, more severe invasive infections can occur, particularly in the very young, the elderly and immunocompromised individuals. Antibiotic therapy is often recommended in these cases. Studies have shown that the odds of invasive infection are up to four times higher with multidrug-resistant *Salmonella* compared to pan-susceptible *Salmonella* [2, 3]. Salmonellosis caused by drug-resistant strains is also associated with a 30–50% longer duration of illness, a three times higher risk of hospitalization and a three times higher risk of death compared to pan-susceptible *Salmonella* [4, 5].

While antibiotic resistance in *Salmonella* is a phenomenon that receives much research attention, there are relatively few studies that quantify changes in resistance over time in specific settings [6]. In Iran, clinical *Salmonella* isolates obtained between 1996 and 2006 showed increased resistance to nalidixic acid

* Author for correspondence: Dr E. I. Broughton, Johns Hopkins Bloomberg School of Public Health, International Health Department, 615 N. Wolfe Street, Baltimore, MD 21205, USA. (Email: ebrought@jhsph.edu)

from 9% to 43% and to ceftazidime from 3% to 23% [7]. Of non-human isolates in the USA between 1999 and 2003, there was increased sulfisoxazole resistance, decreased tetracycline resistance and fluctuating streptomycin resistance [8]. The proportion of resistance remained stable in human and non-human isolates in Austria from 1983 to 2007 [9].

We describe the serovar distribution and antibiotic susceptibility in *Salmonella* collected from human and non-human sources in New Zealand (NZ) from 2002 to 2007. We also assess changes over time in serovar distribution and antibiotic susceptibility using logistic regression. This information is important for gauging the risk that *Salmonella* poses to human health and in aiding the development of rational guidelines for empiric therapy of *Salmonella* infections in humans and for therapeutic and non-therapeutic antibiotic use in animals.

METHODS

Sources and sampling

We analysed results from serotyping and antibiotic susceptibility testing conducted on isolates referred to NZ's Institute of Environmental Science and Research (ESR). All hospital and community laboratories in NZ are requested to refer all isolates from human salmonellosis cases. Salmonellosis is a notifiable disease in NZ and the notification form includes questions on overseas travel within the incubation period. Cases identified as likely to have originated outside NZ were excluded from our analysis. *Salmonella* isolates of non-human origin are referred to ESR from three sources: (1) diagnostic veterinary laboratories that refer isolates obtained predominantly from ill animals, including some post-mortem samples, (2) the NZ Food Safety Authority's programme that refers all isolates obtained from surveillance of processed meats from beef, sheep, poultry, deer and goats [10], and (3) commercial laboratories that refer isolates from food and environmental sources. These non-human samples were classified into three groups: (1) food animals, (2) other food sources, and (3) other sources. Isolates from imported foods were excluded. All isolates referred to ESR are serotyped. The antibiotic susceptibility of a sample of $\sim$600 isolates is tested each year. This sample was obtained by testing every eighth referred isolate in 2002 and every fifth referred isolate from 2003 to 2007.

Laboratory analysis

Salmonella isolates were serotyped using the Kauffmann–White scheme [11]. The CLSI disc diffusion method was used to determine antimicrobial susceptibility [12, 13]. The antibiotics tested were ampicillin (Amp), cephalothin (Cep), chloramphenicol (Chl), ciprofloxacin (Cip), co-amoxiclav (amoxicillin/clavulanic acid, CoAm), cotrimoxazole (Cot), gentamicin (Gen), nalidixic acid (Nal), sulfonamides (Sul), streptomycin (Str), tetracycline (Tet) and trimethoprim (Tri). Co-amoxiclav and nalidixic acid have only been tested since 2004.

Isolates were considered non-susceptible if they were classified as intermediate or resistant according to CLSI interpretive standards [12, 13]. Multidrug non-susceptibility (MDNS) was defined as non-susceptibility to three or more of the tested antibiotics. Non-susceptibility to cotrimoxazole and trimethoprim was considered as a single non-susceptibility as was non-susceptibility to nalidixic acid and ciprofloxacin.

Statistical methods

Given the high number of serovars identified, only the top six were considered separate entities in the analyses and in logistic regression. Isolates identified as serovars not in these six were categorized as 'other' for the purpose of analysis and no conclusions can be drawn for individual isolates in this category.

Logistic regression was used to determine trends over time in serovar distribution and non-susceptibility. An odds ratio (OR) >1 indicates a higher odds of the variable of interest in successive years. For example, an OR of 1·69 for non-susceptibility to streptomycin indicates a 69% increase in the odds of non-susceptibility, on average per year, for each successive year between 2002 and 2007. All analyses were conducted using Stata Intercooled Version 9 (Stata Corp., USA).

RESULTS

Out of the 16640 *Salmonella* isolates referred to ESR from 2002 to 2007, we analysed 3065 (18%) isolates for which serotyping and susceptibility testing was conducted. A total of 1560 (51%) was from human sources and the remaining 1505 (49%) were from non-human sources. The six most common serovars were *S.* Typhimurium, which comprised more than half of human isolates, followed by *S.* Brandenburg,

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Table 1. Salmonella *serovars by source, 2000–2007*

Serovar	2002 *n* (%)	2003 *n* (%)	2004 *n* (%)	2005 *n* (%)	2006 *n* (%)	2007 *n* (%)	Total *n* (%)	OR	*P* value
Human									
Agona	0	1 (0·3)	0	3 (1·1)	5 (2·0)	1 (0·4)	10 (0·6)	1·51	0·05*
Brandenburg	15 (6·1)	12 (3·6)	18 (8·1)	21 (7·4)	8 (3·2)	16 (6·8)	90 (5·8)	1·02	0·76
Enteritidis	18 (7·4)	22 (6·7)	25 (11·3)	21 (7·40	18 (7·3)	35 (15·0)	139 (8·9)	1·13	0·02*
Hindmarsh	1 (0·4)	1 (0·3)	0	1 (0·4)	2 (0·8)	0	5 (0·3)	0·99	0·97
Infantis	12 (4·9)	23 (7·0)	12 (5·4)	7 (2·5)	11 (4·4)	16 (6·8)	81 (5·2)	0·98	0·76
Typhimurium	154 (63·1)	219 (66·6)	125 (56·3)	151 (53·4)	146 (58·9)	118 (50·4)	913 (58·5)	0·89	0·00**
Others	44 (18·0)	51 (15·5)	42 (18·9)	79 (27·9)	58 (23·4)	48 (20·5)	322 (20·6)		
Total	244	329	222	283	248	234	1560		
All non-human									
Agona	2 (1·0)	4 (1·5)	2 (0·8)	9 (3·0)	7 (2·3)	5 (2·4)	29 (1·9)	1·21	0·12
Brandenburg	45 (22·7)	62 (23·4)	59 (24·4)	65 (22·0)	66 (22·1)	39 (18·9)	336 (22·3)	0·96	0·29
Enteritidis	0	1 (0·4)	3 (1·2)	0	1 (0·3)	2 (1·0)	7 (0·5)	1·19	0·48
Hindmarsh	17 (8·6)	12 (4·5)	28 (11·6)	25 (8·4)	32 (10·7)	20 (9·7)	134 (8·9)	1·09	0·13
Infantis	13 (6·6)	14 (5·3)	12 (5·0)	13 (4·4)	11 (3·7))	17 (8·3)	80 (5·3)	1·00	0·95
Typhimurium	75 (37·9)	98 (37·0)	72 (29·8)	111 (37·5)	124 (41·6)	65 (31·6)	545 (36·2)	1·00	0·96
Others	46 (23·2)	74 (27·9)	66 (27·3)	73 (24·6)	57 (19·1)	58 (28·2)	374 (24·9)		
Total	198	265	242	296	298	206	1505		
Food animals									
Agona	2 (1·5)	4 (2·3)	2 (1·3)	9 (3·9)	7 (3·0)	3 (2·3)	27 (2·6)		
Brandenburg	32 (24·2)	48 (27·9)	50 (31·4)	57 (24·9)	59 (25·7)	31 (23·7)	277 (26·3)		
Enteritidis	0	1 (0·6)	0	0	1 (0·4)	0	2 (0·2)		
Hindmarsh	17 (12·9)	12 (7·0)	28 (17·6)	24 (10·5)	32 (13·9)	19 (14·5)	132 (12·5)		
Infantis	10 (7·6)	3 (1·7)	4 (2·5)	5 (2·2)	4 (1·7)	9 (6·9)	35 (3·3)		
Typhimurium	44 (33·3)	68 (39·5)	52 (32·7)	94 (41·0)	95 (41·3)	51 (38·9)	404 (38·4)		
Others	27 (20·5)	36 (20·9)	23 (17·5)	40 (17·5)	32 (13·9)	18 (13·7)	176 (16·7)		
Total	132	172	159	229	230	131	1053		
Other food sources									
Agona	0	0	0	0	0	1 (3·1)	1 (0·6)		
Brandenburg	9 (30·0)	4 (10·3)	5 (17·9)	6 (28·6)	5 (22·7)	5 (15·6)	34 (19·8)		
Enteritidis	0	0	1 (3·6)	0	0	0	1 (0·6)		
Hindmarsh	0	0	0	1 (4·8)	0	1 (3·13)	2 (1·2)		
Infantis	2 (6·7)	8 (20·5)	1 (3·6)	5 (23·8)	7 (31·8)	7 (21·9)	30 (17·4)		
Typhimurium	10 (33·3)	6 (15·4)	4 (14·3)	1 (4·7)	2 (9·1)	2 (6·2)	25 (14·5)		
Others	9 (30·0)	21 (53·8)	17 (60·7)	8 (38·1)	8 (36·4)	16 (50·0)	79 (45·9)		
Total	30	39	28	21	22	32	172		
Other sources									
Agona	0	0	0	0	0	1 (2·3)	1 (0·4)		
Brandenburg	4 (11·1)	10 (18·5)	4 (7·3)	2 (4·3)	2 (4·3)	3 (7·0)	25 (8·9)		
Enteritidis	0	0	2 (3·6)	0	0	2 (4·7)	4 (1·4)		
Hindmarsh	0	0	0	0	0	0	0		
Infantis	1 (2·8)	3 (5·6)	7 (12·7)	3 (6·5)	0	1 (2·3)	15 (5·4)		
Typhimurium	21 (58·3)	24 (44·4)	16 (29·1)	16 (34·8)	27 (58·7)	12 (27·9)	116 (41·4)		
Others	10 (27·8)	17 (31·5)	26 (47·3)	25 (54·3)	17 (40·0)	24 (55·8)	119 (42·5)		
Total	36	54	55	46	46	43	280		

OR, Odds ratio.
Statistically significant: * $P<0·05$, ** $P<0·01$.

S. Infantis, *S*. Enteritidis, *S*. Hindmarsh and *S*. Agona (Table 1). *S*. Enteritidis isolates were almost exclusively from human sources while *S*. Hindmarsh and, to a lesser extent, *S*. Brandenburg were predominantly isolated from non-human sources (Table 1). There were no statistically significant trends over the 6 years in the distribution of the six most common serovars in non-human isolates. Of isolates from human sources,

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Table 2. *Non-susceptible* Salmonella *isolates from human and non-human sources, 2002–2007*

		2002 *n* (%)	2003 *n* (%)	2004 *n* (%)	2005 *n* (%)	2006 *n* (%)	2007 *n* (%)	Total *n* (%)	OR	*P* value
Amp	H	5 (2·0)	2 (0·6)	12 (5·4)	7 (2·5)	11 (4·2)	14 (6·0)	51 (3·3)	1·32	0·00**
	NH	1 (0·5)	3 (1·1)	1 (0·4)	0	1 (0·3)	4 (1·9)	10 (0·7)	1·14	0·51
Cep	H	2 (0·8)	1 (0·3)	2 (0·9)	2 (0·7)	2 (0·8)	3 (1·3)	12 (0·8)	1·16	0·4
	NH	1 (0·5)	4 (1·5)	0	1 (0·3)	0	3 (1·5)	9 (0·4)	0·95	0·82
Chl	H	1 (0·4)	5 (1·5)	4 (1·8)	3 (1·1)	6 (2·4)	4 (1·7)	23 (1·5)	1·17	0·21
	NH	1 (0·5)	4 (1·5)	0	0	0	1 (0·5)	6 (0·1)	0·65	0·12
Cip	H	0	0	1 (0·5)	0	0	1 (0·4)	2 (0·1)	1·5	0·39
	NH	0	0	0	0	0	0	0		
CoAm	H	—	—	3 (1·4)	2 (0·7)	5 (2·0)	2 (0·9)	12 (0·8)	1	1
	NH	—	—	0	0	1 (0·3)	1 (0·5)	2 (0·1)	3·31	0·22
Cot	H	1 (0·4)	5 (1·5)	8 (3·6)	3 (1·1)	4 (1·6)	3 (1·3)	24 (1·5)	1·04	0·73
	NH	0	1 (0·4)	1 (0·4)	1 (0·3)	2 (0·7)	2 (1·0)	7 (0·5)	1·44	0·17
Gen	H	0	0	2 (0·9)	0	0	0	2 (0·1)	0·86	0·72
	NH	0	0	0	0	0	0	0		
Nal	H	—	—	12 (5·4)	12 (4·2)	10 (4·0)	10 (4·3)	44 (2·8)	0·92	0·57
	NH	—	—	1 (0·4)	0	0	2 (1·0)	3 (0·2)	1·69	0·38
Sul	H	5 (2·0)	11 (3·3)	13 (5·9)	7 (2·5)	12 (4·8)	21 (9·0)	69 (4·3)	1·27	0·00**
	NH	8 (4·00)	12 (4·5)	5 (2·1)	4 (1·3)	16 (5·4)	31 (15·0)	76 (5·0)	1·39	0·00**
Str	H	12 (4·9)	48 (14·3)	53 (23·9)	20 (7·1)	75 (30·2)	136 (58·6)	344 (22·1)	1·69	0·00**
	NH	9 (4·5)	45 (17·0)	76 (31·4)	27 (9·1)	59 (19·8)	157 (76·2)	373 (24·8)	1·7	0·00**
Tet	H	6 (2·5)	9 (2·7)	15 (6·8)	8 (2·8)	13 (5·2)	16 (6·8)	67 (4·3)	1·2	0·02*
	NH	5 (2·5)	11 (4·2)	5 (2·1)	7 (2·4)	7 (2·3)	8 (3·9)	43 (2·9)	1	0·98
Tri	H	1 (0·4)	5 (1·5)	7 (3·2)	3 (1·1)	4 (1·6)	3 (1·3)	23 (1·5)	1·05	0·69
	NH	0	2 (.8)	1 (0·4)	1 (0·3)	1 (0·3)	2 (1·0)	7 (0·5)	1·19	0·48
MDNS	H	3 (1·2)	8 (2·4)	13 (5·9)	9 (3·2)	12 (4·8)	16 (6·8)	61 (3·9)	1·29	0·00**
	NH	3 (1·5)	10 (3·8)	4 (1·7)	3 (1·0)	4 (1·3)	10 (4·9)	34 (2·3)	1·07	0·53
Total	H	244	329	222	283	248	234	1560		
	NH	198	265	242	296	298	206	1505		

Amp, ampicillin; Cep, cephalothin; Chl, chloramphenicol; Cip, ciprofloxacin; CoAm, amoxicillin/clavulanic acid; Cot, cotrimoxazole; Gen, gentamicin; Nal, nalidixic acid; Sul, sulfonamides; Str, streptomycin, Tet, tetracycline; Tri, trimethoprim; MDNS, multidrug non-susceptibility to $\geqslant 3$ antibiotics; OR, odds ratio; H, human sources of *Salmonella* isolates; NH, non-human sources of *Salmonella* isolates;
Statistically significant: * $P<0{\cdot}05$, ** $P<0{\cdot}01$.

there were statistically significant increases in *S.* Agona and *S.* Enteritidis (OR 1·51 and 1·13, respectively) while there was a significant decrease in the odds of an isolate being *S.* Typhimurium by a factor of 0·89 over successive years (Table 1).

Overall during the 6-year period, 22% of isolates from human sources and 25% of isolates from non-human sources were non-susceptible to streptomycin. Five percent or fewer of the human or non-human isolates were non-susceptible to any of the other antibiotics. Almost all isolates from all sources were susceptible to ciprofloxacin and gentamicin (Table 2). Between 2002 and 2007, there was a significant trend of increasing non-susceptibility to streptomycin and sulfonamides in isolates from both human and non-human sources, while ampicillin, tetracycline and MDNS also increased in human isolates (Table 2).

Table 3 shows the serovar distribution for the five most commonly occurring antibiotic non-susceptibilities and MDNS. There was a high prevalence of streptomycin non-susceptibility in all the common serovars except for the five *S.* Hindmarsh isolates from humans. Ninety percent (27/30) of MDNS *S.* Typhimurium from non-human sources were non-susceptible to sulfonamides, streptomycin and tetracycline with 26% (7/27) of these also non-susceptible to trimethoprim and ampicillin. Of human MDNS *S.* Typhimurium isolates, 87% (13/15) were non-susceptible to sulfonamides, streptomycin and tetracycline with 77% (10/13) of these also non-susceptible to ampicillin. Eight (5·8%) *S.* Enteritidis isolates were MDNS with variable non-susceptibility patterns. Although there were only ten human *S.* Agona isolates, there was a high rate of non-susceptibility in

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Table 3. *Non-susceptibility to selected antibiotics by serovar and source*

	Amp		Sul		Str		Tet		Nal	MDNS	
Serovar	H *n* (%)	NH *n* (%)	H *n* (%)	NH *n* (%)	H *n* (%)	NH *n* (%)	H *n* (%)	NH *n* (%)	H* *n* (%)	H *n* (%)	NH *n* (%)
Agona	1 (10·0)	0	3 (30·0)	0	6 (60·0)	6 (20·7)	3 (30·0)	0	3 (30·0)	4 (40·0)	0
Brandenburg	2 (2·2)	0	5 (5·6)	23 (6·8)	23 (25·6)	104 (31·0)	1 (1·1)	0	0	1 (1·1)	0
Enteritidis	11 (7·9)	0	6 (4·3)	0	55 (39·6)	4 (57·1)	7 (5·0)	0	15 (15·2)	8 (5·8)	0
Hindmarsh	0	0	0	1 (0·7)	0	26 (19·4)	0	0	0	0	0
Infantis	0	0	3 (3·7)	1 (1·2)	19 (23·5)	16 (20·0)	0	2 (2·5)	0	2 (2·5)	1 (1·3)
Typhimurium	17 (1·9)	8 (1·5)	21 (2·3)	45 (8·3)	137 (15·0)	116 (21·3)	20 (2·2)	35 (6·4)	5 (0·1)	15 (1·6)	30 (5·5)
Other	20 (6·2)	2 (0·5)	31 (9·6)	6 (1·6)	104 (32·3)	101 (27·0)	36 (11·2)	6 (1·6)	21 (9·3)	31 (9·6)	3 (0·8)

Amp, ampicillin; Sul, sulfonamides; Str, streptomycin, Tet, tetracycline; Nal, nalidixic acid; MDNS, multidrug non-susceptibility to $\geqslant 3$ antibiotics; H, human sources of *Salmonella* isolates; NH, non-human sources of *Salmonella* isolates.
* Nal susceptibility from non-human sources not included because there were only three: one *S*. Agona, one *S*. Infantis and one other serovar.

Table 4. *Non-susceptibility of non-human isolates to selected antibiotics by source*

	Food animals					
	Bovine *n* (%)	Ovine *n* (%)	Poultry *n* (%)	Other food animals *n* (%)	Other food sources *n* (%)	Other sources *n* (%)
Amp	7 (2·6)	0	0	1 (14·3)	1 (0·6)	1 (0·4)
Sul	34 (12·7)	16 (4·7)	11 (2·5)	1 (14·3)	9 (5·2)	5 (1·8)
Str	80 (29·9)	84 (24·6)	92 (21·1)	1 (14·3)	48 (27·9)	68 (24·3)
Tet	31 (11·6)	0	5 (1·1)	1 (14·3)	2 (1·2)	4 (1·4)
Tri	6 (2·2)	0	0	1 (14·3)	0	0
Total	268	342	436	7	172	280

Amp, ampicillin; Sul, sulfonamides; Str, streptomycin, Tet, tetracycline; Tri, trimethoprim.
Other food animals includes isolates from 4 pigs, 2 deer and 1 goat.
Other sources includes isolates from environmental samples and other animals such as felines and canines.

them with three being non-susceptible to chloramphenicol, nalidixic acid, sulfonamides, streptomycin and tetracycline. *S*. Hindmarsh was the most susceptible of the six most common serovars.

Table 4 shows non-susceptibilty, in the groups of non-human isolates, to the five antibiotics to which non-susceptibility was most common in all non-human isolates. Bovines had the highest levels of antibiotic non-susceptibility in the food animals. Ampicillin, tetracycline and trimethoprim non-susceptibility was rarely seen in ovine or poultry isolates.

DISCUSSION

In NZ salmonellosis is the second most commonly notified bacterial gastrointestinal illness after campylobacteriosis. The annual rate of notified cases of human salmonellosis averaged 34/100 000 population throughout the 2002–2007 period [14–18]. The majority of cases were caused by *S*. Typhimurium, although the proportion of cases due to this serovar decreased during our study period. This predominance of *S*. Typhimurium in human isolates is different to the global pattern of serovar distribution identified in the WHO's Global Salm-Surv worldwide surveillance [19], but consistent with findings in Australia and North America [19, 20]. *S*. Typhimurium was also the predominant serovar in non-human isolates, which is consistent with the global pattern.

S. Brandenburg appears to be more common in NZ than in any other setting, due to its emergence and rapid spread in sheep from 1998 onwards. Accordingly, this serovar has been associated with sheep farmers in NZ [21]. We found no change in the

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proportion of *S*. Brandenburg since 2002 in human or non-human isolates.

NZ had a much lower proportion of non-susceptible *Salmonella* from humans in 2002 compared to many other settings [22, 23]. Despite some significant increases in non-susceptibility during the study period, there is still a smaller proportion of non-susceptible isolates in NZ than in other countries [22, 24]. The statistically significant increase in MDNS *Salmonella* since 2002 in human isolates was mostly due to the increased non-susceptibility to ampicillin, streptomycin and sulfonamides. These antibiotics are generally not used to treat clinical salmonellosis cases. While there was almost universal susceptibility to ciprofloxacin, the relatively high level of non-susceptibility to nalidixic acid, especially in *S*. Enteritidis, suggests caution should be used in treating invasive infection with fluoroquinolones [25].

The high level of non-susceptibility to streptomycin in *Salmonella* from non-human sources that we found is consistent with findings in several other countries [26–29]. Streptomycin is widely used in cattle and sheep farming in NZ, although this use has been declining since 2001 [30]. Tetracycline non-susceptibility was lower than that found elsewhere [26–29]. While tetracycline is used for prophylaxis and therapy, its use as a growth promotant is banned in NZ and the level of use is thought to be lower than in other settings [30]. Overall, there was a lower prevalence of non-susceptibility to ampicillin than reported in other surveys, possibly due to the very low levels of use in food animals [30]. The statistically significant increase in non-susceptibility to sulfonamides in this study was consistent with a study by Kiessling *et al*. [8] that found only limited changes in overall antibiotic susceptibility occurring over time, with increasing resistance to sulfisoxazole and decreasing resistance to tetracycline from 1999–2003 in isolates from imported and USA domestic samples.

S. Typhimurium was more likely to be MDNS than the other common serovars for non-human isolates. This serovar has been found to have high levels of MDNS in other studies in both human [31, 32] and non-human isolates [27, 31]. Of human isolates here, a higher proportion of *S*. Agona and *S*. Enteritidis were MDNS than *S*. Typhimurium.

One weakness of this study is that humans infected with less virulent and pathogenic *Salmonella* will have more mild illness and be less likely to seek medical attention than those infected with more virulent and pathogenic serovars. Therefore the isolates represented here and in any similar surveillance system are likely to represent only the more pathogenic strains of the bacteria.

There may also have been biases in the reporting of both human and non-human isolates from foreign sources. While isolates from patients with a history of overseas travel and from imported foods were excluded when they were identified, it is possible that the reporting system did not identify all such isolates. There is generally a higher level of non-susceptibility found in foreign isolates, so failure to exclude all of these may result in higher non-susceptibility in this sample, although the possible impact of this is likely to be small. It is possible that samples from veterinary diagnostic sources may not represent a random sample of *Salmonella* isolates. Veterinarians may be more likely to send for further analysis those samples from cases in which first-line treatment has failed thereby increasing the proportion of non-susceptible isolates. Representativeness of the samples may also be compromised by changes in the proportions of animal species tested and the geographical location of the sources from year to year.

Pigs have been identified as an important source of *Salmonella* in several studies [27, 33, 34]. However, only four porcine isolates were included in our study. This is partially a reflection of the relatively small size of the NZ pork industry in comparison to other livestock industries, and the fact that the NZ Food Safety Authority has not included pork in its processed meats surveillance programme. The Authority is planning to include pork in future surveillance [35].

Another potential weakness in the study is the inherent difficulty of susceptibility testing. Streptomycin testing can be a particular challenge because many *Salmonella* isolates may have inhibition zone diameters very close to the breakpoints [36, 37]. The ESR laboratory participates in the Global Salm-Surv's External Quality Assurance System and in 2007 obtained 100% agreement with streptomycin susceptibility results. However, this was not always the case in previous years.

In view of the growing threat to public health that drug-resistant bacteria pose, tracking changes in *Salmonella* serovars and antibiotic susceptibility is important to assess the risk of exposure to foodborne pathogens and to guide appropriate management of salmonellosis in humans and animals. This study demonstrates that antibiotic-resistant *Salmonella* in NZ presents a lower threat than in many international settings but this has increased during the 2002–2007

period. We recommend continued surveillance and ongoing analysis of these trends over time.

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DECLARATION OF INTEREST

None.

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