CHAPTER 12

ANTIMICROBIAL SUSCEPTIBILITY IN *SALMONELLA*

Salmonella isolates received for serological identification at AHVLA Weybridge and Lasswade are tested for their *in vitro* sensitivity to 16 antimicrobials. The majority of these isolates originate from animals and their environment in England and Wales; some isolates (mainly from poultry) originate from Scotland. Isolates which have been recovered under the Control of *Salmonella* in Broilers, Poultry and Turkeys Orders are included. The choice of antimicrobials, which is reviewed periodically, is designed to comprise a core set which has been used in veterinary practice for many years, as well as some of the more recently licensed antimicrobials and some of limited or no usage in animals in Great Britain, but which are used in human medicine. All tests are performed using the British Society for Antimicrobial Chemotherapy (BSAC) disc diffusion technique (www.bsac.org.uk) on Oxoid "Isosensitest" agar and antimicrobial discs as listed in the table overleaf. BSAC recommendations have also been adopted in relation to most breakpoints, where BSAC breakpoints are available. Changes made to breakpoints over the years have been catalogued in previous reports and include revisions made to enhance the detection of resistance to third generation cephalosporins and fluoroquinolones.

In 2007, the interpretative criterion was changed for ciprofloxacin from the historical AHVLA veterinary breakpoint of resistant $\leq$ 13mm used in previous years, to the BSAC breakpoint of resistant or intermediate $\leq$ 19mm (this breakpoint was recommended by BSAC on 1st January 2007). Trends in ciprofloxacin resistance should therefore be interpreted taking into account this change to the breakpoint. Where no BSAC breakpoints are available, then the historical AHVLA veterinary breakpoint has been used. This has been checked by considering minimum inhibitory concentration (MIC) and zone size data (AHVLA data on file, published in the UK-VARSS Report 2012). The only change made to the breakpoints and disc concentrations used over the period 2008 - 2013 related to the ceftazidime disc where the zone size was reduced from 29mm to 26mm in 2012, in line with BSAC recommendations.

	Antimicrobial	Concentration (µg per ml)	Code	Zone Size (R≤x mm)
1	Nalidixic acid	30	NA	13
2	Tetracycline	10	T	13
3	Neomycin	10	N	13
4	Ampicillin	10	AM	13
5	Furazolidone	15	FR	13
6	Ceftazidime	30	CAZ	26
7	Sulphamethoxazole/ trimethoprim	25	TM	15
8	Chloramphenicol	30	C	20
9	Amikacin	30	AK	18
10	Amoxicillin/clavulanic acid	30	AMC	14
11	Gentamicin	10	CN	19
12	Streptomycin	10	S	13
13	Sulphonamide compounds	300	SU	13
14	Cefotaxime	30	CTX	29
15	Apramycin	15	APR	13
16	Ciprofloxacin	1	CIP	19

Prior to 1996, all *Salmonella* isolates received were tested for antimicrobial susceptibility, but since then only the first isolate of a given serovar or phage type from each incident has usually been tested. The number of cultures received from a farm varies enormously, especially in the case of those received from poultry premises. Some poultry companies have a continuous monitoring programme and large numbers of *Salmonella* isolates may be received from a particular company relating to one premises. Thus, in that situation, the numbers of isolates of a particular serovar and their antimicrobial susceptibility may not reflect the prevalence in the animal population as a whole but rather the intensity of the monitoring programme on a farm or group of farms. Therefore, to better indicate the prevalence of resistance, only the first isolate from each incident has usually been tested since the start of 1996.

SALMONELLA DUBLIN

Of the 393 *Salmonella* Dublin cultures tested during 2013, 96.9% were susceptible to all 16 antimicrobials (Table 12.1). The percentage of *S.* Dublin isolates sensitive to all 16 antimicrobials has shown only slight fluctuations over the period 2001 - 2013 and the majority of isolates remain susceptible. This has been the situation since surveillance began in 1971. Most *S.* Dublin isolates (90.9%) originated from cattle in

2013 which was similar to the situation in previous years. Resistance to ampicillin, which had been observed for the first time for several years in a very low number of bovine isolates in 2000, was not recorded in any *Salmonella* Dublin cultures in 2001 or 2002 and then re-appeared in 2003 - 2013 (Table 12.1). Resistance to furazolidone was not detected in 2010 - 2013. No isolates resistant to trimethoprim/ sulphonamides have been detected since 2006. Resistance to streptomycin was detected in 1.8% of cultures in 2012 and 1.3% in 2013. Neomycin resistance was observed in a single isolate from cattle in 2013, whilst nalidixic acid resistance was seen in three bovine isolates and a single isolate from laying chickens. No resistance was detected in 2013 against any of the antimicrobials in the panel of 16 which were tested but which are not shown in Table 12.1, apart from a single isolate from cattle which was resistant to gentamicin. Of the 12 *S*. Dublin isolates showing antimicrobial resistance in 2013, each was only resistant to a single compound in the panel of antimicrobials tested.

SALMONELLA **TYPHIMURIUM**

A total of 165 isolates of *Salmonella* Typhimurium were examined in 2013. The eight most frequent definitive or undefined phage types subjected to susceptibility testing at AHVLA are displayed in Figure 12.1. Just over a quarter (28.5%) of *S.* Typhimurium isolates tested in 2013 were DT104, DT104b or U302 (Table 12.2). The percentage of the eight most common definitive and undefined types of *Salmonella* Typhimurium sensitive to all 16 antimicrobial agents in 2013 is given in Figure 12.2. Almost a third (30.3%) of all *Salmonella* Typhimurium isolates were sensitive to all of the antimicrobials tested (Table 12.2), which is a slight increase from the figure of 27.2% observed in 2012. The generally high level of resistance of *S.* Typhimurium isolates observed in recent years has been partly a reflection of the contribution of DT104 and its variants DT104b and U302, only 14.9% (7/47) of which were sensitive to all the antimicrobials tested in 2013. Although the proportion of *S.* Typhimurium isolates comprising DT104 and its variants has declined significantly in recent years, the phage types which are currently prevalent are also frequently resistant.

S. Typhimurium U288 and DT193 from pigs comprised 12.7% and 13.3% of the total number of *S*. Typhimurium isolates tested in 2013, respectively; none of them were fully susceptible. AmSSuTTm was the most common resistance pattern observed in DT193 isolates from pigs (15/22 isolates) whereas AmCSSuTTm was the most common resistance pattern recorded in U288 isolates from pigs (13/21 isolates).

The typical pentavalent resistance pattern AmCSSuT was the most common resistance pattern seen in *S*. Typhimurium DT104 and 104b, occurring in 8/25 isolates. Three further isolates had this pentavalent resistance pattern with additional resistances including resistance to trimethoprim/ sulphonamides or nalidixic acid.

There were no *Salmonella* Typhimurium isolates resistant to ceftazidime, cefotaxime, amoxicillin/clavulanate, furazolidone or amikacin recovered in 2013.

Twelve percent (3/25) of DT104 and DT104b isolates (from all sources) were resistant to nalidixic acid in 2013 and 4.0% (1/25) were resistant to sulphamethoxazole/trimethoprim. The sulphamethoxazole/trimethoprim resistant isolate originated from a broiler, whilst the nalidixic acid resistant isolates were all from cattle. No isolates of DT104 were recovered from turkeys in 2012 or 2013, but isolates from turkeys have commonly shown nalidixic acid resistance in previous years. Nalidixic acid resistance in *S.* Typhimurium DT104 by species of origin is listed in Table 12.3 for the main food-producing species

Considering all definitive phage types of *S*. Typhimurium, a marked increase in resistance to sulphamethoxazole/trimethoprim from levels of around 16-24% in 1996-2001 to 33%-58% in 2002-2007 was observed and discussed in previous reports. In 2008, the prevalence of resistance was 26.4%, although in 2009 it increased to 40.7%; it was 27.1% in 2010, 37.5% in 2011, 41.9% in 2012 and 44.8% in 2013. In relation to other phage types of *S*. Typhimurium, it has been predominantly pig isolates that have accounted for these fluctuations in sulphamethoxazole/trimethoprim resistance (Table 12.4). A high proportion of many definitive types of *S*. Typhimurium isolated from pigs are resistant to sulphamethoxazole/trimethoprim.

The definitive and undefined phage types of *S*. Typhimurium resistant to sulphamethoxazole/trimethoprim recovered from pigs in 2013 included contributions primarily from isolates belonging to DT193 and U288. The total numbers of isolates of these types and the percentage resistant to trimethoprim/ sulphonamides are shown in Table 12.5.

Resistance to neomycin was detected in 1.4% (1/71) of *S*. Typhimurium isolates from pigs in 2013; the isolate was phage type U288. Over the period 2006 - 2012 the main contribution to the overall levels of neomycin resistance seen in *S.* Typhimurium has come from isolates from pigs belonging to DT193 and U288 or which have been untypable using phages.

Apramycin resistance had increased to 20.4% in *S*. Typhimurium in 2011 and 2012. This was a notable change in comparison with preceding years where apramycin resistance has been consistently less than 5%. In 2013, apramycin resistance in *S.* Typhimurium declined markedly to 1.8%. Each apramycin-resistant isolate was also resistant to gentamicin. Two of the isolates originated from pigs and were DT193; the third was from a non-farmed species and was untypable.

Ciprofloxacin resistance was detected in a single *S*. Typhimurium DT99 isolate from pheasants in 2013. This isolate was also resistant to nalidixic acid.

Multiple antibiotic resistance (i.e. resistance to four or more antimicrobial agents in the panel of 16) was detected in definitive and undefined phage types DT104, U288 and U302 from cattle, in DT104, DT104b and DT120 from poultry (i.e. chickens) and in DT32, DT104, DT120, DT193, U288 and U302 from pigs. Of the 18 different definitive and undefined phage types of *S*. Typhimurium detected and tested in 2013, five (namely DT1, DT40, DT41b, DT66a and DT8) were fully susceptible to all of the antimicrobials in the test panel.

MONOPHASIC *SALMONELLA* SEROVARS

Fifty-nine isolates of *Salmonella* 4,12:i:- were examined, belonging to phage types DT40 (n=1), DT104b (n=2), DT120 (n=3), DT193 (n=44) and U311 (n=1). Eight isolates were not typable. Most of the isolates were from pigs (47.5%) with horses the second most common source (22.0%). The most common pattern of resistance observed was AmSSuT, occurring in 19/44 DT193 isolates, the single U311 isolate and 3/8 of the untypable isolates. Thirty-eight (86.4%) of the DT193 isolates had either the basic AmSSuT resistance pattern or one or more additional resistances.

A total of 109 isolates of *Salmonella* 4,5,12:i:- were examined, including phage types DT8 (n=1), DT40 (n=4), DT41 (n=3), DT104b (n=1), DT120 (n=8), DT193 (n=73), U310 (n=1), U311 (n=8) and U323 (n=3). Seven isolates were untypable. The most common resistance pattern among DT193 was AmSSuT, occurring in 61.6% (45/73) of those isolates. Most of the DT193 isolates were from pigs (49.3%) or cattle (19.2%).

SEROVARS OTHER THAN *SALMONELLA* DUBLIN AND *SALMONELLA* TYPHIMURIUM

Of the 2,328 isolates of serovars other than *S*. Dublin and *S*. Typhimurium tested, 61.2% were sensitive to all of the antimicrobials in the panel (Table 12.6). This represented an increase on the figure reported in 2012 (56.7%). Twenty-one isolates of *S.* Enteritidis were tested, twenty (95.2%) of which were fully susceptible. A single isolate of *S.* Enteritidis PT1b from a cat was resistant to nalidixic acid; one further isolate of this phage type (also from a cat) was fully susceptible, as were the remaining isolates which belonged to PT2 (n=1), PT4 (n=4), PT8 (n=5), PT9a (n=2), PT11 (n=2), PT12 (n=1), PT13a (n=1), PT14b (n=1), PT20 (n=1) and PT28 (n=1).

Neomycin resistant isolates originated mainly from ducks (188 isolates; 22.9% resistant) and chickens (832 isolates; 2.9% resistant). The majority of the neomycin-resistant isolates from chickens were *Salmonella* Ohio (the same situation prevailed in 2011 and 2012) with only single isolates of other serovars resistant to neomycin (*S.* Livingstone, *S.* Mbandaka, *S.* Montevideo and a rough strain). In ducks, serovars showing resistance to neomycin included *S*. Indiana (95 isolates; 36.8% resistant) and *S.* Bredeney (7 isolates; all resistant). The *S.* Indiana isolates from ducks were also frequently resistant to furazolidone (95 isolates; 42.1% resistant).

The apparent increase in the prevalence of resistance to streptomycin, sulphonamides and tetracylines from 2009 reflects in part the increased monitoring of turkeys that has occurred in 2010 - 2013 under the Control of *Salmonella* in Turkeys Order. Considering *Salmonella* isolates other than Typhimurium and Dublin from turkeys in 2013 (n=241), 68.0% were resistant to streptomycin, 60.6% to sulphonamides and 56.8% to tetracyclines, which is similar to the equivalent figures for pigs in 2013 (65 - 74%) but higher than those for chickens (10 - 21%) and cattle (14 - 16%).

INDIVIDUAL ANTIMICROBIALS

Of the 2,886 salmonellas examined in 2013, 1,853 (64.2%) were sensitive to all of the antimicrobials tested (Table 12.7). This is similar to the situation in 2012, when 2,536 *Salmonellas* were examined and 59.7% were sensitive to all of the antimicrobials tested. Considering all *Salmonella* isolates from pigs, the number fully susceptible rose from 7.8% in 2009 to 17.9% in 2010 and 23.7% in 2011; however, it thereafter declined to 12.5% in 2012 and 12.9% in 2013. The fluctuation was primarily related to the occurrence of two fully susceptible *S*. Typhimurium phage types (DT9 and DT41b) in 2011 in pigs, which were not detected in 2012 or 2013, and is possibly due to a shift in strains with different resistance profiles.

Tetracycline resistance was most commonly observed in *Salmonella* isolates originating from pigs and turkeys in 2013. This was also the situation for resistance to sulphonamides and streptomycin.

Resistance to apramycin was detected in 1.2% of all *Salmonella* serovars in 2013, which was a decline on the figures of 3.2% in 2012 and 5.3% in 2011 and a return to levels seen in 2010 (0.9%). The rise in 2011-2012 was principally accounted for by *Salmonella* isolates from pigs, where resistance was 0.7% in 2008, 7.0% in 2009, 6.9% in 2010, 22.7% in 2011 and 26.4% in 2012. In 2013, resistance to apramycin in *Salmonella* from pigs declined to 7.9% (similar to the levels seen in 2009 and 2010). In 2012, 37.4% of *S.* Typhimurium isolates (n=99), 40.0% of *S.* 4,12:i:- isolates (n=25) and 12.0% of *S.* 4,5,12:i:- isolates (n=50) from pigs were resistant to apramycin (and also resistant to gentamicin). This can be contrasted with the situation in 2013, when 2.8% of *S*. Typhimurium (n=71), 39.3% of *S.* 4,12:i:- isolates (n=28) and 2.1% of *S.* 4,5,12:i:- isolates (n=47) from pigs were resistant to apramycin. Resistance to both apramycin and gentamicin, which is observed in most apramycin-resistant isolates, suggests involvement of the enzyme AAC(3)IV. However, 0.7% of all *Salmonella* isolates were resistant to gentamicin but not apramycin, including five *S*. Mbandaka isolates and two *S.* Montevideo isolates from broilers and two *S*. Kentucky isolates from dogs. No resistance was detected to the aminoglycoside amikacin in 2013.

Over the period 2008-2012, 2-3% of all *Salmonella* isolates were resistant to nalidixic acid per year. In 2013, 5.0% resistance was observed. The highest prevalence of resistance was observed in *Salmonella* isolates from turkeys and the category “other avian species”, similar to the position seen in 2012. In turkeys, 40/55 *S*. Newport and 5/5 *S*. Senftenberg isolates tested in 2013 were resistant to nalidixic acid. The situation in turkeys was similar in 2012 with nalidixic acid resistance detected in more than half of the *S.* Newport isolates and all *S.* Senftenberg isolates. Considering other avian species, a single nalidixic acid resistant *S.* Typhimurium isolate was detected in both pigeons and pheasants, whilst nalidixic acid resistant *S*. Binza was detected in laying chickens, partridges and pheasants (n=5). Nalidixic acid resistant *S*. Indiana (n=3) and *S.* Orion (n=1) were observed in ducks. In broilers, resistance to nalidixic acid was primarily observed in *S*. Indiana (15/15 isolates), *S.* Infantis (21/22 isolates), *S.* Senftenberg (16/127 isolates) and in a rough strain (O-rough:g,s,t:-) of which 9/10 isolates were resistant to nalidixic acid and to ciprofloxacin. Ciprofloxacin resistance was detected in 2013 in broiler chickens (*S.* Senftenberg (n=3) and a rough strain (n=9)), dogs (*S.* Kentucky (n=2)), partridges (rough strain (n=1)), pheasants (*S.* Binza (n=1) and *S*. Typhimurium (n=1)) and turkeys (*S.* Newport (n=17)). Most isolates were also resistant to nalidixic acid

Trimethoprim/sulphonamide resistance in *Salmonella* isolates from pigs declined from 56.1% in 2009 to 35.0% in 2010, although thereafter increased again to 42.0% in 2011, 47.2% in 2012 and 55.6% in 2013. The serovars contributing most trimethoprim/sulphonamide resistant isolates to the total *Salmonella* figure for pigs in 2013 were *S.* Typhimurium (71 isolates; 93.0% resistant), *Salmonella* 4,12:i:- (28 isolates; 57.1% resistant), *Salmonella* 4,5,12:i:- (47 isolates; 19.1% resistant) and *S.* Kedougou (eight isolates; all resistant). Trimethoprim/sulphonamide resistance was also observed in *S.* Kedougou from turkeys (19 isolates; 52.6% resistant) and broilers (98 isolates; 69.4% resistant).

Resistance to amoxicillin/clavulanate was observed in 21.3% (10/47) of *S.* 4,5,12:i:- isolates from pigs. These isolates were assumed to be hyper-producers of beta-lactamase, since they were susceptible to cefotaxime and ceftazidime. All of the isolates showed the same pattern of resistance to ampicillin, streptomycin, sulphonamides, tetracyclines and amoxicillin/ clavulanate.

Resistance to ceftazidime or cefotaxime was only detected in a single isolate of the monophasic *Salmonella* 4,12:i:- from pigs in 2013. The isolate was also resistant to ampicillin, streptomycin, sulphonamides, tetracyclines and chloramphenicol.

PUBLIC HEALTH CONSIDERATIONS

Antimicrobial susceptibility patterns are often useful in conjunction with *Salmonella* serovar and (where appropriate) phage type data to investigate the epidemiology of *Salmonella* infections in humans and animals. When new serovars or phage types or patterns of resistance emerge in humans, comparative analysis can be done to provide an indication of the possible role or involvement of UK livestock. Ad-hoc liaison in this way between the Agencies concerned, as considered appropriate and necessary, is ongoing.

Resistance to third generation cephalosporins and fluoroquinolones is considered of greatest public health importance, since these antimicrobials are particularly relevant for the treatment of human salmonellosis, where this is required. [It should be noted that most cases of non-typhoidal *Salmonella* infection in humans are non-invasive and limited to the gastro-intestinal tract and do not require treatment with antimicrobials]. Only 1.2% of *Salmonella* isolates were resistant to ciprofloxacin and a single isolate was resistant to ceftazidime and cefotaxime in 2013. The occurrence of ciprofloxacin resistance in *S*. Typhimurium from cattle, pigs and turkeys is currently at a low level, but requires ongoing monitoring to assess future trends because this serotype is of major public health importance. Attempts are made for an AHVLA veterinarian to visit all cases of *Salmonella* infection in food-producing animals with resistance to third generation cephalosporins or ciprofloxacin, both to explain the significance of the findings and to provide appropriate advice on control.

A new development in 2013 was the detection of two isolates of *S.* Kentucky from epidemiologically unrelated incidents in dogs. The isolates were resistant to ciprofloxacin, nalidixic acid, ampicillin, gentamicin, sulphonamides and tetracyclines, with one isolate additionally resistant to streptomycin. Both isolates were sequence type 198, and showed high-level ciprofloxacin resistance (ciprofloxacin MIC $\geq$ 8mg/ l). *S.* Kentucky with these characteristics has been detected in Africa and the Middle East, as well as in travellers to those areas, since 2000 and has subsequently been detected in poultry in some European countries. The source of infection for the two dogs was not determined.

Table 12.1: *Salmonella* Dublin: antimicrobial susceptibility monitoring 2001 - 2013

Year	No of cultures	Percentage susceptible to all 16 antimicrobials*	Percentage of cultures resistant to:										
			AM	C	NA	S	APR	CN	N	FR	SU	TM	T
2001	467	98.3	-	0.6	0.2	0.2	-	-	-	-	1.3	0.2	-
2002	687	97.5	-	0.4	-	0.3	-	0.1	0.4	0.6	0.7	0.9	0.6
2003	949	96.4	0.6	1.3	0.2	1.4	-	-	0.2	0.4	1.2	0.4	0.8
2004	516	97.9	0.2	0.8	0.2	1.0	-	-	-	-	1.2	0.8	0.4
2005	365	98.1	0.8	0.3	-	1.1	-	-	-	-	0.3	-	0.3
2006	468	96.4	0.9	0.6	1.5	0.4	-	-	0.2	-	1.3	0.2	0.6
2007	381	98.7	0.2	-	-	0.8	-	-	-	-	-	-	0.2
2008	404	96.0	0.3	0.3	0.3	3.2	-	-	-	0.3	0.3	-	0.5
2009	560	92.3	0.5	0.4	0.4	7.0	-	-	-	0.2	0.5	-	0.9
2010	630	95.7	0.2	0.2	1.3	2.7	-	0.2	-	-	0.5	-	-
2011	453	96.0	0.2	0.4	0.4	3.3	0.2	-	-	-	0.4	-	0.4
2012	327	97.2	0.6	0.3	0.6	1.8	-	-	-	-	-	-	0.3
2013	393	96.9	0.3	-	1.0	1.3	-	0.3	0.3	-	-	-	-

* For a key to the antimicrobials used please see the table towards the beginning of this chapter

Table 12.2: *Salmonella* Typhimurium: antimicrobial susceptibility monitoring 2001 - 2013

Year	No of cultures	Percentage susceptible to all 16 antimicrobials*	Percentage of cultures resistant to:									
			AM	C	NA	S	APR	N	FR	SU	TM	T
2001	519 [a]	20.6	66.7	55.9	11.9	57.8	2.3	2.9	0.4	71.7	24.3	75.5
2002	533 [b]	14.5	70.5	62.1	7.1	61.0	2.4	3.4	2.6	77.9	44.1	80.1
2003	613 [c]	19.6	68.5	58.9	13.5	61.7	3.8	6.2	0.7	73.1	37.5	74.2
2004	468 [d]	26.7	58.5	49.4	10.0	55.8	1.5	4.5	0.6	63.7	32.7	65.6
2005	552 [e]	24.1	67.2	53.1	8.9	60.0	0.7	1.3	4.2	71.6	36.1	71.0
2006	1136 [f]	24.2	65.9	57.0	6.9	54.2	1.0	5.1	1.0	70.2	39.8	69.2
2007	1057 [g]	11.4	78.4	58.8	4.5	70.6	1.5	4.5	0.6	85.3	57.9	81.6
2008	709 [h]	19.6	66.2	43.0	3.5	65.7	1.0	1.6	-	70.7	26.4	73.8
2009	440 [i]	25.7	61.1	46.1	4.1	60.7	1.1	3.0	0.2	67.5	40.7	65.7
2010	328 [j]	33.5	51.2	36.3	5.2	54.6	4.0	3.0	0.3	56.7	27.1	58.2
2011	427 [k]	34.4	49.2	24.6	4.9	51.3	20.4	3.5	-	56.2	37.5	57.4
2012	191 [l]	27.2	56.5	30.4	2.6	59.1	20.4	2.1	0.5	63.9	41.9	64.9
2013	165 [m]	30.3	57.6	35.2	4.8	54.5	1.8	0.6	-	60.6	44.8	61.2

* For a key to the antimicrobials used please see the table towards the beginning of this chapter

[a] 274 (52.8%) of these strains were DT104 and its variants
[b] 239 (44.8%) of these strains were DT104 and its variants
[c] 273 (44.5%) of these strains were DT104 and its variants
[d] 139 (29.7%) of these strains were DT104 and its variants
[e] 144 (26.1%) of these strains were DT104 and its variants
[f] 316 (27.8%) of these strains were DT104 and its variants
[g] 181 (17.1%) of these strains were DT104 and its variants
[h] 171 (24.1%) of these strains were DT104 and its variants
[i] 64 (14.5%) of these strains were DT104 and its variants
[j] 45 (13.7%) of these strains were DT104 and its variants
[k] 52 (12.2%) of these strains were DT104 and its variants
[l] 35 (18.3%) of these strains were DT104 and its variants
[m] 47 (28.5%) of these strains were DT104 and its variants

Table 12.3: Nalidixic acid resistance in *Salmonella* Typhimurium DT104 from domestic livestock in 2001 - 2013. Number of cultures tested (percentage resistant to nalidixic acid)

Year	Livestock species					
	Cattle	Sheep	Pigs	Chickens	Turkeys	Ducks
2001	115 (15.7)	8 (12.5)	19 (21.1)	22 (0.0)	25 (60.0)	0 (0.0)
2002	67 (7.5)	5 (40.0)	36 (5.6)	32 (0.0)	17 (11.8)	0 (0.0)
2003	100 (20.0)	6 (0.0)	27 (11.1)	12 (8.3)	41 (63.4)	0 (0.0)
2004	44 (0.0)	2 (0.0)	10 (10.0)	6 (0.0)	39 (74.4)	0 (0.0)
2005	40 (12.5)	8 (0.0)	2 (0.0)	6 (33.3)	32 (96.9)	0 (0.0)
2006	112 (0.0)	12 (0.0)	20 (0.0)	6 (50.0)	57 (71.9)	0 (0.0)
2007	33 (3.0)	7 (0.0)	22 (0.0)	5 (0.0)	11 (100.0)	0 (0.0)
2008	29 (3.4)	5 (0.0)	34 (0.0)	6 (0.0)	0 (0.0)	0 (0.0)
2009	25 (8.0)	1 (0.0)	13 (15.4)	2 (0.0)	0 (0.0)	0 (0.0)
2010	19 (0.0)	2 (0.0)	3 (0.0)	5 (0.0)	2 (100.0)	0 (0.0)
2011	16 (18.8)	1 (0.0)	0 (0.0)	1 (0.0)	2 (100.0)	0 (0.0)
2012	6 (0.0)	2 (0.0)	5 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
2013	9 (33.3)	0 (0.0)	1 (0.0)	8 (0.0)	0 (0.0)	0 (0.0)

Table 12.4: Trimethoprim/sulphonamide resistance in *Salmonella* Typhimurium (all phage types) from domestic livestock in 2004 - 2013. Number of cultures tested (percentage resistant to trimethoprim/sulphonamide)

Year	Livestock species					
	Cattle	Sheep	Pigs	Chickens	Turkeys	Ducks
2004	90 (30.0)	7 (57.1)	146 (71.9)	11 (0.0)	55 (1.8)	7 (0.0)
2005	71 (14.1)	13 (30.8)	317 (56.2)	10 (20.0)	37 (2.7)	13 (0.0)
2006	174 (20.1)	18 (27.8)	555 (69.4)	13 (15.4)	86 (7.0)	35 (14.3)
2007	86 (4.7)	10 (0.0)	792 (75.0)	10 (0.0)	24 (0.0)	3 (0.0)
2008	76 (0.0)	6 (0.0)	404 (42.1)	39 (0.0)	20 (0.0)	8 (0.0)
2009	70 (0.0)	4 (0.0)	237 (70.5)	41 (7.3)	1 (0.0)	11 (0.0)
2010	63 (4.8)	5 (20.0)	108 (66.7)	25 (4.0)	5 (40.0)	44 (9.1)
2011	39 (15.4)	1 (0.0)	244 (60.7)	20 (10.0)	6 (0.0)	40 (2.5)
2012	15 (6.7)	5 (0.0)	99 (72.7)	9 (22.2)	0 (0.0)	4 (0.0)
2013	24 (12.5)	0 (0.0)	71 (93.0)	12 (8.3)	0 (0.0)	3 (0.0)

Table 12.5: Trends in trimethoprim/sulphonamide resistance in certain types of *Salmonella* Typhimurium from pigs over the period 2002 - 2013. Number of cultures tested (percentage resistant to trimethoprim/sulphonamide)

Year	Definitive or undefined phage type			
	DT193	DT208	U288	U308a
2002	47 (85.1)	14 (100.0)	51 (94.1)	59 (94.9)
2003	38 (92.1)	7 (42.9)	72 (90.3)	0 (0.0)
2004	19 (78.9)	1 (100.0)	71 (97.2)	3 (0.0)
2005	134 (43.3)	0 (0.0)	107 (96.3)	0 (0.0)
2006	103 (71.8)	16 (25.0)	229 (96.1)	0 (0.0)
2007	239 (65.3)	7 (14.3)	374 (97.3)	0 (0.0)
2008	153 (35.3)	28 (28.6)	106 (95.3)	0 (0.0)
2009	71 (69.0)	2 (50.0)	100 (98.0)	0 (0.0)
2010	35 (57.1)	1 (0.0)	38 (89.5)	0 (0.0)
2011	39 (46.2)	1 (0.0)	55 (96.4)	0 (0.0)
2012	24 (62.5)	0 (0.0)	34 (94.1)	0 (0.0)
2013	22 (91.0)	0 (0.0)	21 (100.0)	0 (0.0)

Figure 12.1: Number of isolates of *S*. Typhimurium of the eight most frequent phage types subjected to susceptibility testing at AHVLA 2004 - 2013

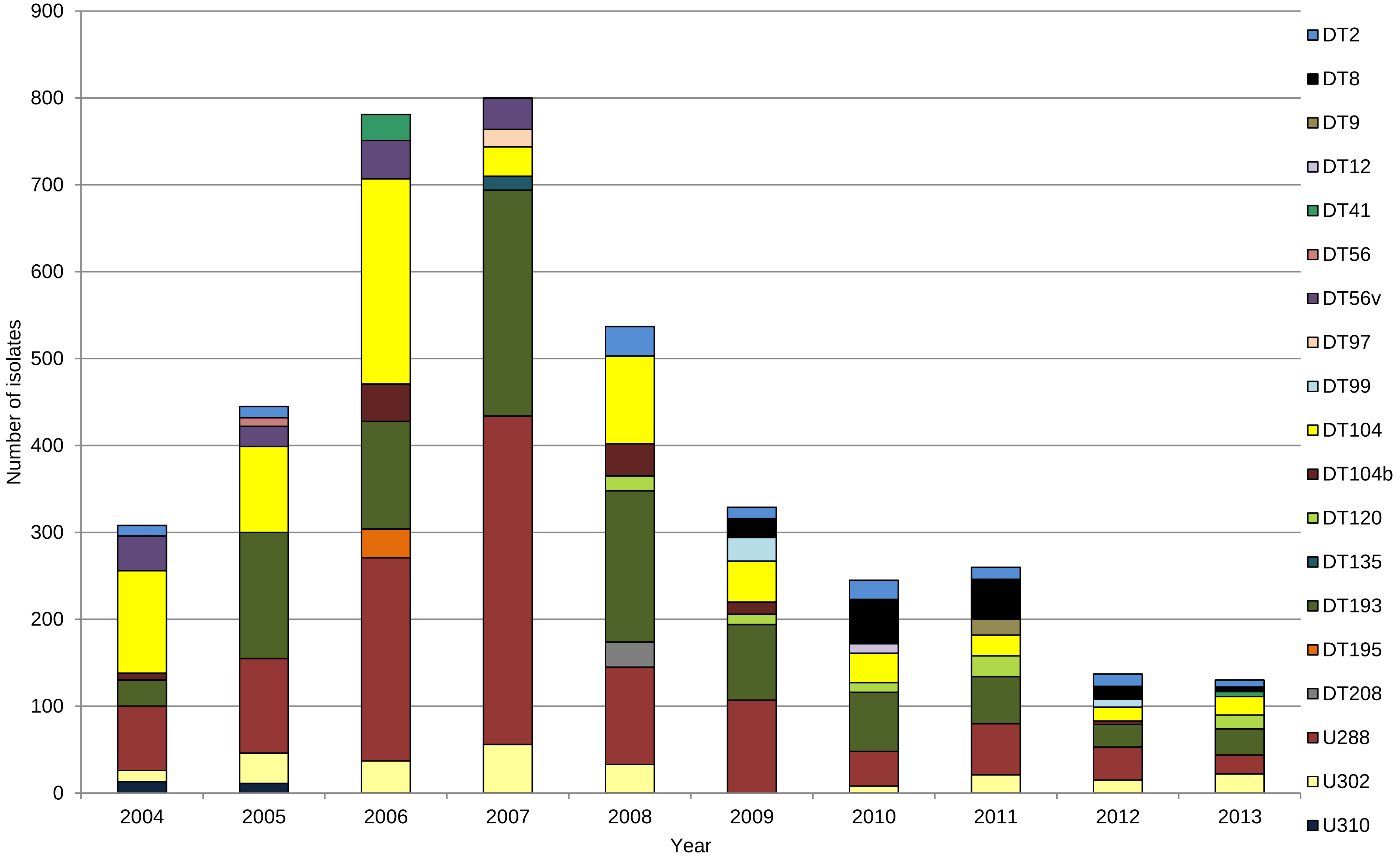

Figure 12.2: Percentage of the eight most common definitive and undefined phage types of *Salmonella* Typhimurium susceptible to all 16 antimicrobial agents in 2013

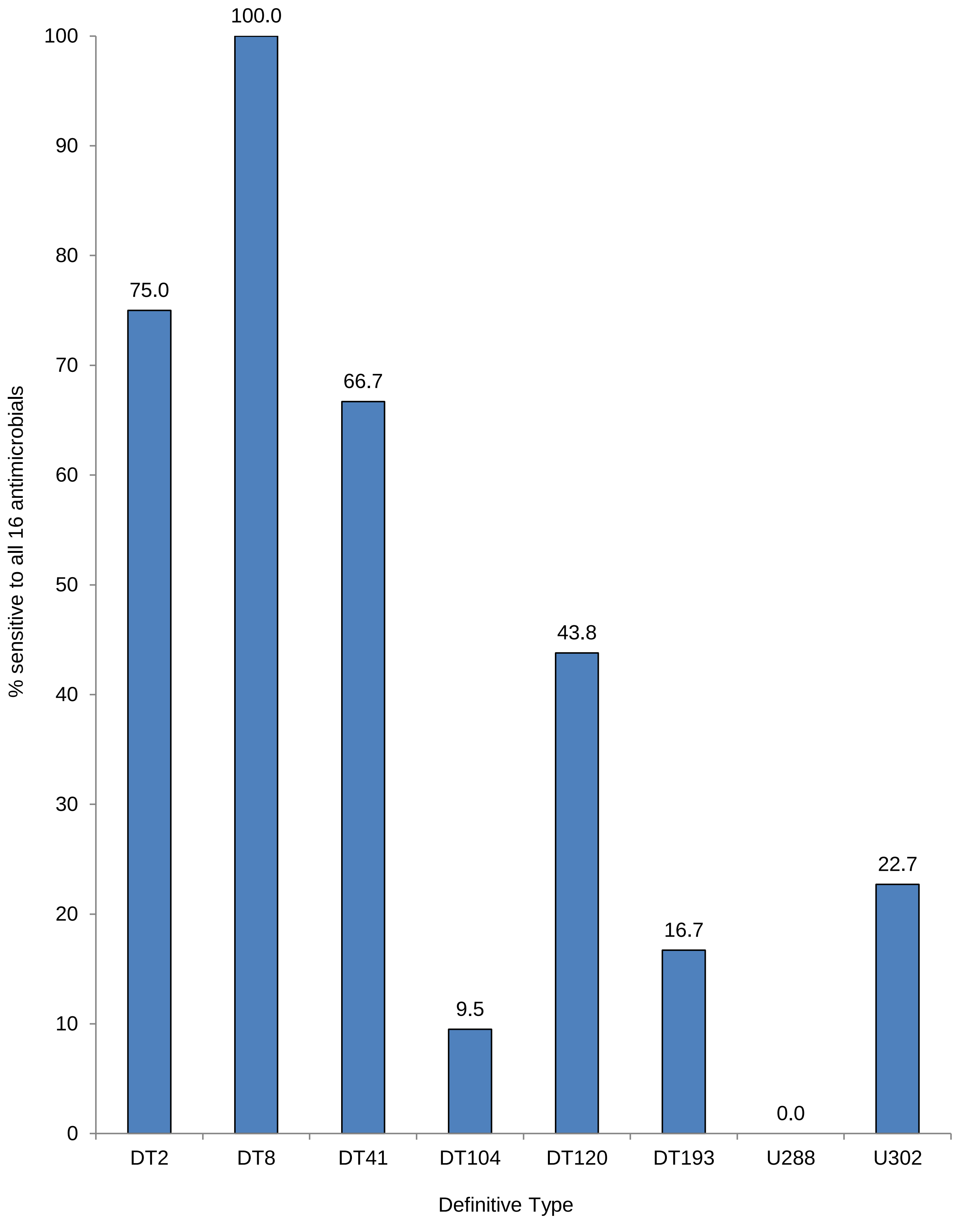

Table 12.6: *Salmonella* other than *Salmonella* Dublin and *Salmonella* Typhimurium: antimicrobial susceptibility monitoring 2001 - 2013

Year	No of cultures	Percentage susceptible to all 16 antimicrobials*	Percentage of cultures resistant to:									
			AM	C	NA	S	APR	N	FR	SU	TM	T
2001	1814	69.8	5.7	6.4	1.4	8.1	0.2	1.0	0.6	20.0	12.1	10.0
2002	2167	60.3	6.5	8.0	1.9	11.2	0.3	5.2	3.7	24.0	19.5	13.7
2003	3652	67.7	4.4	4.5	2.2	10.0	0.1	6.2	8.7	19.0	12.4	15.7
2004	2942	67.3	2.2	1.3	2.1	11.6	0.3	7.2	7.8	19.1	14.0	17.5
2005	2683	65.6	4.6	2.5	2.2	10.9	0.1	4.2	6.2	23.7	12.3	23.6
2006	2727	58.7	7.2	3.2	4.0	15.8	0.2	6.9	5.7	25.1	14.2	28.8
2007	2248	63.4	7.7	2.2	3.4	12.8	0.2	4.0	3.5	22.2	11.9	28.8
2008	2474	67.3	5.0	1.8	1.8	14.0	0.3	3.2	1.3	17.5	8.1	23.7
2009	1990	64.0	8.1	2.5	2.1	16.4	1.7	4.1	2.9	23.2	12.6	24.4
2010	2126	56.7	12.9	1.3	1.8	29.1	0.7	3.4	0.8	35.7	11.2	32.5
2011	1982	56.4	16.3	3.6	2.6	27.2	3.2	2.7	0.2	35.1	13.6	31.1
2012	2018	56.7	13.9	1.7	4.0	25.0	2.0	3.6	1.5	33.1	12.2	33.4
2013	2328	61.2	12.3	1.7	5.7	19.2	1.4	3.4	3.1	26.5	12.2	28.0

* For a key to the antimicrobials used please see the table towards the beginning of this chapter

Table 12.7: All salmonellas: antimicrobial susceptibility 2013

Species	No of isolates	Percentage susceptible to all 16 antimicrobials*	Percentage of isolates resistant to:														
			AM	AMC	CAZ	CTX	C	NA	CIP	S	APR	CN	N	FR	SU	TM	T
Cattle	518	90.7	5.0	-	-	-	1.0	1.4	-	6.2	-	0.2	0.2	-	5.4	0.8	6.2
Sheep	91	94.5	2.2	-	-	-	-	-	-	2.2	-	1.1	-	-	2.2	-	2.2
Pigs	178	12.9	74.4	5.6	0.6	0.6	28.1	1.7	-	74.7	7.9	8.4	2.8	-	84.3	55.6	79.2
Chickens	850	64.2	7.4	-	-	-	3.9	8.0	1.4	10.9	2.4	3.5	2.8	2.8	21.8	10.9	20.9
Turkeys	242	14.9	31.0	-	-	-	0.4	20.2	7.0	67.8	-	0.4	0.4	0.8	60.3	10.7	56.6
Ducks	191	67.5	4.7	-	-	-	0.5	2.1	-	25.1	-	-	22.5	23.0	7.9	4.2	23.6
Geese	1	100.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Horses	54	57.4	35.2	-	-	-	3.7	-	-	37.0	-	-	-	-	38.9	1.9	38.9
Dogs	50	46.0	42.0	-	-	-	2.0	6.0	4.0	32.0	-	4.0	-	-	42.0	4.0	38.0
Other non-avian species	285	72.3	4.9	-	-	-	0.7	1.1	-	5.6	0.4	0.7	1.1	0.4	22.1	18.2	24.9
Other avian species†	48	58.3	14.6	-	-	-	4.2	14.6	6.3	18.8	2.1	2.1	2.1	-	14.6	2.1	27.1
Feed	28	92.9	-	-	-	-	-	-	-	-	-	-	-	-	7.1	7.1	7.1
Environment	350	70.9	3.7	-	-	-	0.3	-	-	2.6	-	0.3	1.1	-	21.7	19.1	26.3
TOTAL	**2886**	**64.2**	**13.2**	**0.3**	**0.03**	**0.03**	**3.4**	**5.0**	**1.2**	**18.8**	**1.2**	**1.9**	**2.8**	**2.5**	**24.8**	**12.4**	**26.1**

* For a key to the antimicrobials used please see the table towards the beginning of this chapter

† Budgerigars, lorikeets, parrots, partridges, pheasants, pigeons and quails

No isolates were resistant to amikacin