Antimicrobial Resistance Report: *Veterinary Public Health*

This report presents data from submissions to the British Columbia (BC) Ministry of Agriculture's Animal Health Centre (AHC) between January 1, 2007 and December 31, 2015. This report is focused on antimicrobial resistance in bacteria with public health significance. The goal is to provide information that may be of interest to public health officials. The specific bacteria-antimicrobial combinations included in the report were chosen based on significance to public health, and the number of isolates from AHC submissions. This report summarizes AHC data for methicillin-resistance in *Staphylococcus* spp. isolates; and ceftiofur, enrofloxacin, sulfa-trimethoprim and tetracycline resistance in *Salmonella* spp. and *Escherichia coli* (*E. coli*) isolates.

All data was generated from bacterial isolates from passively-acquired submissions to the AHC. Classification of bacterial isolates as resistant or susceptible to antimicrobials was made in accordance with Clinical Laboratory Standards Institute (CLSI) protocols using Kirby-Bauer disk diffusion (CLSI, 2012). Isolate sources included animals submitted for post mortem examination, fecal samples, environmental samples from animal-rearing facilities and swabs collected by veterinarians in clinical practice. Some important limitations to passively collected diagnostic data include that samples are likely to originate from individuals that are sick or unthrifty, and for domestic animals, might be more likely to have received antimicrobial treatment; and that AHC submission numbers are comparatively small relative to total number of animals in BC. As such, inferences about antimicrobial resistance in the source population of animals in BC must be made cautiously and apparent trends will require further verification.

Methicillin Resistance in *Staphyloccocus* spp.

Background

Staphylococcus spp., including *Staphylococcus aureus (S. aureus)* and *Staphylococcus intermedius (S. intermedius)* are gram-positive bacteria commonly found on the skin and mucous membranes of animals and humans. *S. aureus* and *S. intermedius* can also act as disease-causing pathogens in animals and humans. *S. aureus* isolates that are resistant to β-lactam antimicrobials (e.g., penicillins such as oxacillin, methicillin and dicloxacillin) are called methicillin-resistant *Staphylococcus aureus* (MRSA). Resistance occurs when the *mecA* gene produces an altered penicillin-binding protein (PBP2a), reducing the bacteria's affinity for binding beta-lactams. Cefoxitin is used preferentially over methicillin and oxacillin to test for MRSA because cefoxitin is a strong inducer of the *mecA* gene, and provides the most reproducible and accurate results (CDC, 2013). Nucleic acid amplification tests, such as the polymerase chain reaction (PCR), can be used to detect the *mec*A gene, and will detect some isolates not detected using resistance assays. However, *mec*A PCR tests will not detect novel resistance mechanisms such as *mec*C, or uncommon phenotypes (CDC, 2013). In some instances, MRSA isolates are highly resistant to non- β-lactam antimicrobials (e.g. to erythromycin, fluoroquinolones and tetracycline).

It is estimated that approximately 2% of people carry MRSA. MRSA is more commonly isolated from people with direct contact with livestock. MRSA is of considerable public health significance, causing difficult to treat infections in both community and hospital settings. In BC, it is estimated that as many as 25% of *S. aureus* isolates from laboratory submissions from human skin infections are MRSA (BCCDC, 2014).

The AHC began testing for resistance in all isolates of coagulase-positive *Staphylococcal* spp. in August 2010. The AHC tests all *Staphylococcus* spp. isolates for MRSA using cefoxitin discs as a marker for methicillin resistance. Samples may

be sent out from AHC to other laboratories in cases in which genetic sequencing is indicated. This report uses only data originating from cefoxitin disc testing.

Results

Seven hundred and thirty-eight *Staphylococcal* spp. isolates, including 728 *S. aureus*, 7 *S. intermedius*, and 3 non-speciated coagulase-positive *Staphylococci*, originating from 580 cases, were tested for resistance to cefoxitin between Aug. 17, 2010 and Dec. 31, 2015. Of these, 497 were from animal tissue samples, 1 was from an environmental sample, 1 was from urine, 4 were from fecal samples, 145 were from fluid milk from dairy cattle and 90 were from swabs submitted by veterinarians but for which no source was provided. Of these, 6 of 738 (0.80%) *S. aureus* isolates were resistant: 2 isolates from domestic cats (2012, 2013), 2 from pigs (2010, 2013) and 2 from wild animals (harbour seal in 2010, rock dove in 2012). The isolates from companion animals and wild animals were tested only for resistance to cefoxitin, so multiple resistance data are not available. The 2010 pig isolate was susceptible to 6/6 non- β-lactam antimicrobials. The 2013 pig isolate was susceptible to 4/6 non- β-lactam antimicrobials.

Table 1. Origin of coagulase-positive *Staphylococcal* spp. isolates screened for cefoxitin resistance at the AHC between August 17, 2010 and December 31, 2015.

Animal Type[a]	Total Isolates	Resistant isolates	Isolates per Year		
			Minimum	Mean	Maximum
Chicken (broilers)	244	0	20	37	54
Chicken (layers)	35	0	3	5	10
Turkeys	34	0	0	5	12
Pigs	21	2	0	3	5
Cattle (beef)	5	0	0	<1	2
Cattle (dairy)	146	0	7	21	35
Other food animals	47	0	0	4	14
Companion animals	59	2	1	9	18
Other animals and birds[1]	147	2	6	23	64

[a]Submissions were classified into animal type by evaluation of species and breed data. The category 'other food animals' includes sheep and goats, as well as poultry and cattle where the breed or production type was not specified. 'Companion animals' include any animal deemed to be in close contact with people, including horses. 'Other animals and birds' includes wild animals, and non-food producing domestic animals (i.e. mink).

Commentary

Less than 1% of *Staphylococcal* spp. isolates tested for cefoxitin resistance at AHC were classified as MRSA. Although sample size was small, 9.5% of *Staphylococcal* spp. isolates from pigs were MRSA, suggesting a need for ongoing MRSA monitoring in pigs.

Antimicrobial Resistance in *Salmonella*

Background

Salmonella can be found in the intestines of healthy food-producing animals, such as poultry and pigs, or can act as disease causing pathogens in animals and people. Human salmonellosis occurs after ingestion of bacteria from contaminated animal-origin foods, and to a lesser extent, contaminated plant-origin foods, as well as through direct contact with animals. There are over 2000 strains of *Salmonella* spp. that can cause salmonellosis. In Canada, the three strains causing the majority of human illness are *Salmonella* Enteritidis, *Salmonella* Heidelberg and *Salmonella* Typhimurium (CIPARS 2013).

Reporting of antimicrobial resistance in *Salmonella* is included in most antimicrobial resistance monitoring programs, including the Canadian Integrated Program on Antimicrobial Resistance Surveillance (CIPARS). CIPARS uses active sampling to monitor antimicrobial resistance in *Salmonella* isolated from farms, abattoirs and retail meat from broiler chickens, pigs and turkeys. CIPARS also monitors AMR in *Salmonella* isolates passively collected from sick chickens, turkeys, cattle, pigs and horses. Isolates from sick animals are generated from routine submissions to private and provincial animal health laboratories, including the AHC, and are forwarded from these laboratories to CIPARS on a voluntary basis.

AHC data used to generate this report identified *Salmonella* at the serogroup level; serotype data was not available. At the AHC, four different panels for antimicrobial resistance testing of *Salmonella* are in use: mammalian gram-negative, avian gram-negative, porcine, and milk. Ceftiofur, sulfa-trimethoprim and tetracycline are common to all four panels and each represents a different antimicrobial class. The fluoroquinolone Enrofloxacin is common to the mammalian gram-negative and avian gram-negative panels, but not the porcine or milk panels. In Canada, ceftiofur and enrofloxacin are classified as ‘very high importance’ in human medicine, while sulfa-trimethoprim is classified as ‘high importance’ and tetracycline is classified as ‘medium importance’ (Health Canada, 2009).

In this section of the report, results are presented as tables showing resistance in *Salmonella* isolates to ceftiofur, enrofloxacin, sulfa-trimethoprim and tetracycline by animal type. This is followed by graphs of proportion of resistant isolates (with 95% confidence intervals) by animal type for t meat-type chickens (broilers and broiler-breeders), turkeys, pigs, and dairy cattle. These animal types were chosen because there were a sufficient number of isolates to present data graphically.

Results

Eight hundred and fifty-eight *Salmonella* isolates, originating from 742 cases, were tested for antimicrobial resistance between January 1, 2007 and December 31, 2015. Of these, 759 were from animal tissue samples, 44 were from fecal samples, five were from environmental samples, two were from eggs and one was from a fluff sample. The site of origin for forty-seven swabs submitted by veterinarians could not be determined. A mean of 82 isolates were tested per year with a minimum of 46 isolates (2008) and a maximum of 158 isolates (2015) tested in one year.

Table 2. Origin of *Salmonella* isolates screened for antimicrobial resistance at the AHC between January 1, 2007 and December 31, 2015.

Animal type[a]	Total Isolates	Isolates per year		
		Minimum	Mean	Maximum
Chicken (meat-type)	387	11	37	136
Chicken (layer)	12	0	1	4
Turkeys	94	1	10	17
Pigs	62	4	6	11
Cattle (dairy)[b]	74	0	8	16
Cattle (beef)	3	0	<1	2
Other food animals	56	0	4	20
Companion animals	30	1	3	5
Other animals and birds	140	4	12	28

[a]Submissions were classified into animal type by evaluation of species and breed data. The category 'other food animals' includes sheep and goats, as well as poultry and cattle where the breed or production type was not specified. 'Companion animals' include any animal deemed to be in close contact with people, including horses. 'Other animals and birds' includes wild animals, and non-food producing domestic animals (i.e. mink).
[b]Of 74 *Salmonella* isolates from dairy cattle, 48 were from animal tissues and 26 were from feces. There were no *Salmonella* isolates from fluid milk.

Table 3. *Salmonella* serogroup by animal type for *Salmonella* isolates from submissions to the AHC.

Animal type[a]	*Salmonella* serogroup						
	B	C1/C4	C2/C3	D1	E4	G1	Missing
Chickens (meat-type)	15	10	57[c]	198[d]	1	3	103
Chickens (layer)	3	1	3[b]	4[c]	0	0	1
Turkeys	29	9	12	5	12	1	26
Pigs	33[e]	8	0	4	4	5	8
Cattle (dairy)[b]	42[e]	0	1	27[f]	0	0	4

[a]Submissions were classified into animal type by evaluation of species and breed data. Poultry and cattle where the breed or production type was not specified were classified as 'other food animals' and are not included in the table.
[b]Of 74 *Salmonella* isolates originating from dairy type cattle, 48 were from animal tissues and 26 were from feces. There were no *Salmonella* isolates from fluid milk.
[c]For AHC chicken submissions, *Salmonella* Kentucky is the most common serotype in serogroup C2/C3.
[d]For AHC chicken submissions, *Salmonella* Enteriditis is the most common serotype in serogroup D1. During summer 2015, an outbreak of *Salmonella* Enteriditis associated with a hatchery resulted in increased testing.
[e]For AHC pig and dairy cattle submissions, *Salmonella* Typhimurium is the most common serotype in serogroup B.
[f]For AHC dairy cattle submissions, *Salmonella* Dublin is the most common serotype in serogroup D1.

Table 4. Proportion of *Salmonella* isolates susceptible to 4 antimicrobials (ceftiofur, enrofloxacin, sulfa-trimethoprim and tetracycline) by animal type[a] and year.

	Proportion pan-susceptible					Number of isolates				
	Chickens-meat type	Chickens-layers	Turkeys	Pigs[c]	Dairy cattle	Chickens-meat type	Chickens-layers	Turkeys	Pigs	Dairy cattle
All years	.77	.75	.44[b]	.31	.26	387	12	94	62	74
2007	.63[b]	1.0[b]	.20[b]	0	.25	11	3	5	5	12
2008	.38[b]	1.0[b]	0[b]	.60	.13	16	1	1	5	8
2009	.71	0	.33	.27	.21	38	1	12	11	14
2010	.77	.50	.67	.17	.25	30	4	3	6	8
2011	.82	1.00	.27	.33	.13	72	1	15	6	8
2012	.67	1.00	.15	.25	.67	15	1	13	4	4
2013	.87	1.00	.71	.20	.31	24	1	14	10	16
2014	.85	-	.57	0	.50	47	0	14	5	4
2015	.87	-	.31	.50	-	136	0	17	10	0

[a]Submissions were classified into animal type by evaluation of species and breed data. The category dairy cattle includes 48 isolates from animal tissues and 26 from feces. There were no *Salmonella* isolates from fluid milk. Poultry and cattle where the breed or production type was not specified were classified as 'other food animals' and are not included in the table.

[b]For poultry, isolates were not tested for resistance to sulfa-trimethoprim in 2007 and 2008, therefore we report the proportion susceptible to three antimicrobials (enrofloxacin, ceftiofur and tetracycline) for those years.

[c]For pigs, isolates were not tested for resistance to enrofloxacin, therefore we report the proportion susceptible to three antimicrobials (ceftiofur, sulfa-trimethoprim and tetracycline).

Table 5. Proportion of *Salmonella* isolates resistant to ceftiofur by animal type[a] and year.

	Proportion resistant to ceftiofur					Number of isolates				
	Chickens-meat type	Chickens-layers	Turkeys	Pigs	Dairy cattle	Chickens-meat type	Chickens-layers	Turkeys	Pigs	Dairy cattle[b]
All years	.16	.08	.27	.05	.19	387	12	94	62	74
2007	.22	0	.25	0	0	9	3	5	5	12
2008	.56	0	0	0	0	16	1	1	5	8
2009	.21	1.0	.42	0	0	38	1	12	11	14
2010	.17	0	0	0	.25	30	4	3	6	8
2011	.14	0	.60	0	.38	72	1	15	6	8
2012	0	0	.15	0	0	15	1	13	4	4
2013	.08	0	.21	.10	.44	24	1	14	10	16
2014	.19	-	.21	.40	.50	47	0	14	5	4
2015	.10	-	.23	.13	-	136	0	17	10	0

[a]Submissions were classified into animal type by evaluation of species and breed data. Poultry and cattle where the breed or production type was not specified were classified as 'other food animals' and are not included in the table.

[b]The category dairy cattle includes 48 isolates from animal tissues and 26 from feces. There were no *Salmonella* isolates from fluid milk.

Table 6. Proportion of *Salmonella* isolates resistant to enrofloxacin by animal type[a] and year.

	Proportion resistant to enrofloxacin				Number of isolates			
	Chickens-meat type	Chickens-layers	Turkeys	Dairy cattle	Chickens-meat type	Chickens-layers	Turkeys	Dairy cattle
All years	0	0	0	0	387	12	94	74
2007	0	0	0	0	9	3	5	12
2008	0	0	0	0	16	1	1	8
2009	0	0	0	0	38	1	12	14
2010	0	0	0	0	30	4	3	8
2011	0	0	0	0	72	1	15	8
2012	0	0	0	0	15	1	13	4
2013	0	0	0	0	24	1	14	16
2014	0	0	0	0	47	0	14	4
2015	0	0	0	0	136	0	17	0

[a]Submissions were classified into animal type by evaluation of species and breed data. Poultry and cattle where the breed or production type was not specified were classified as 'other food animals' and are not included in the table. The porcine panel used at AHC for antimicrobial resistance testing does not include enrofloxacin (or other fluoroquinolones) so fluoroquinolone resistance data for pig isolates was not available.

Table 7. Proportion of *Salmonella* isolates resistant to sulfa-trimethoprim by animal type[a] and year.

	Proportion resistant to sulfa-trimethoprim					Number of isolates				
	Chickens-meat type	Chickens-layers	Turkeys	Pigs	Dairy cattle	Chickens-meat type[b]	Chickens-layers[b]	Turkeys[b]	Pigs	Dairy cattle
All years	<.01	0	0	.02	.30	340	8	82	62	74
2007	-	-	-	0	.33	0	0	0	5	12
2008	-	-	-	0	.75	0	0	0	5	8
2009	0	0	0	0	.43	16	1	6	11	14
2010	0	0	0	0	.13	30	4	3	6	8
2011	0	0	0	0	.13	72	1	15	6	8
2012	0	0	0	0	.25	15	1	13	4	4
2013	0	0	0	.10	.18	24	1	14	10	16
2014	0	-	0	0	0	47	0	14	5	4
2015	.02	-	0	0	-	136	0	17	10	0

[a]Submissions were classified into animal type by evaluation of species and breed data. Poultry and cattle where the breed or production type was not specified were classified as 'other food animals' and are not included in the table.
[b]The AHC began testing gram-negative bacterial isolated from poultry for resistance to sulfa-trimethoprim began in mid-2009.

Table 8. Proportion of *Salmonella* isolates resistant to tetracycline by animal type[a] and year.

	Proportion resistant to tetracycline					Number of isolates				
	Chickens-meat type	Chickens-layers	Turkeys	Pigs	Dairy cattle	Chickens-meat type	Chickens-layers	Turkeys	Pigs	Dairy cattle
All years	.15	.17	.38	.64	.74	389	12	94	62	74
2007	.27	0	.80	1.0	.75	11	3	5	5	12
2008	.13	0	1.00	.40	.88	16	1	1	5	8
2009	.16	0	.58	.72	.78	38	1	12	11	14
2010	.20	.50	.33	.83	.75	30	4	3	6	8
2011	.14	0	.14	.67	.87	72	1	15	6	8
2012	.33	0	.77	.75	.50	15	1	13	4	4
2013	.13	0	.14	.70	.69	24	1	14	10	16
2014	.06	-	.28	.60	.50	47	0	14	5	4
2015	.05	-	.54	.38	-	136	0	17	10	0

[a]Submissions were classified into animal type by evaluation of species and breed data. Poultry and cattle where the breed or production type was not specified were classified as 'other food animals' and are not included in the table.

Antimicrobial resistance in *Salmonella* isolates from meat-type chickens

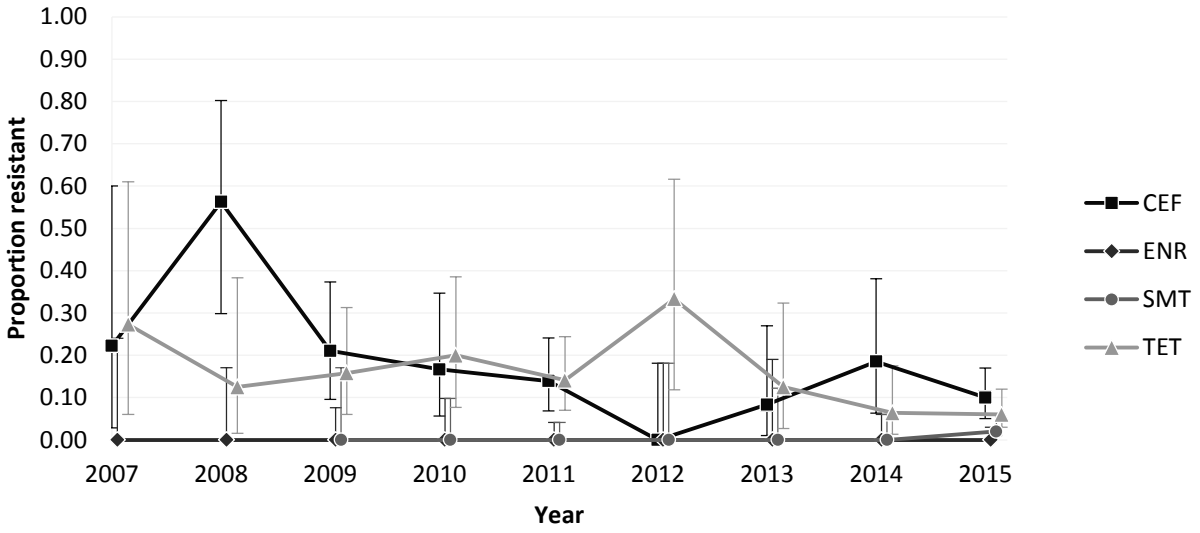

Figure 1: Proportion of *Salmonella* isolates from meat-type chickens submitted to the Animal Health Centre resistant to ceftiofur (CEF), enrofloxacin (ENR), sulfa-trimethoprim (SMT) and tetracycline (TET) by year. Error bars represent 95% confidence intervals for the proportion calculated by the Clopper-Pearson exact binomial method.

Antimicrobial resistance in *Salmonella* isolates from turkeys

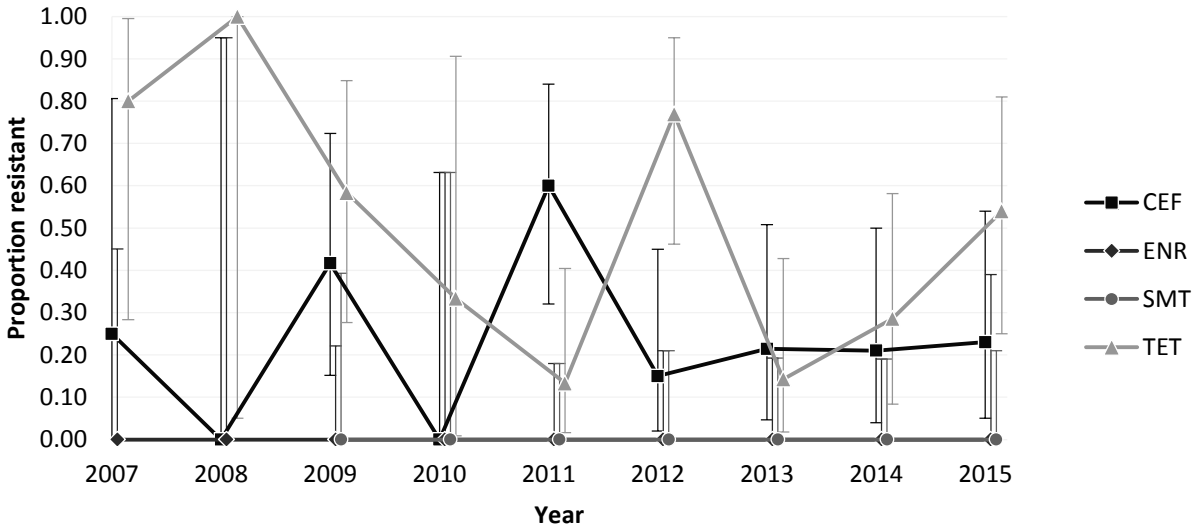

Figure 2: Proportion of *Salmonella* isolates from turkeys submitted to the Animal Health Centre resistant to ceftiofur (CEF), enrofloxacin (ENR), sulfa-trimethoprim (SMT) and tetracycline (TET) by year. Error bars represent 95% confidence intervals for the proportion calculated by the Clopper-Pearson exact binomial method.

Antimicrobial resistance in *Salmonella* isolates from pigs

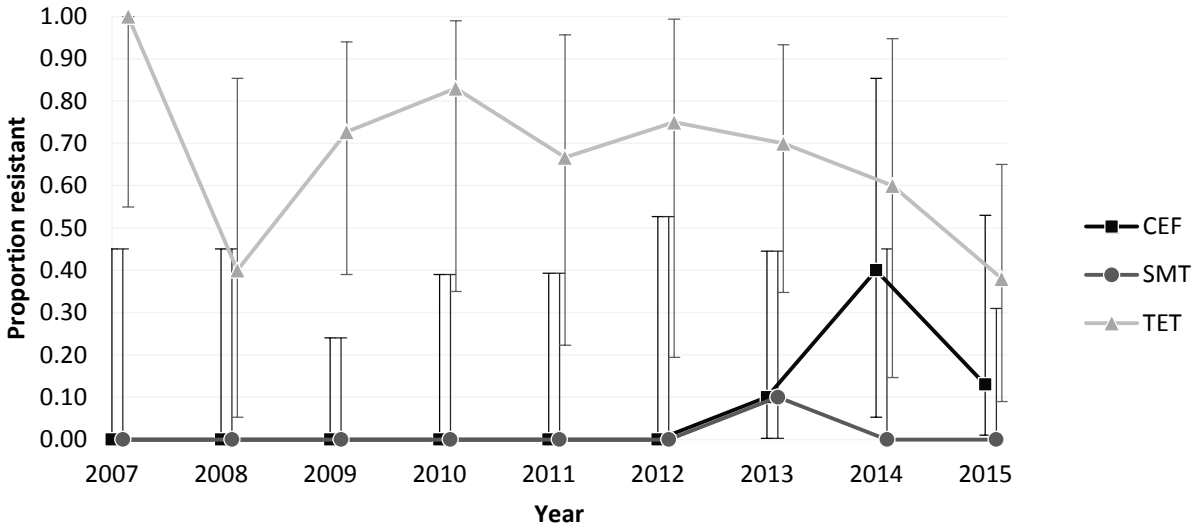

Figure 3: Proportion of *Salmonella* isolates from pigs submitted to the Animal Health Centre resistant to ceftiofur (CEF), sulfa-trimethoprim (SMT) and tetracycline (TET) by year. Pig isolates were not tested for resistance to enrofloxacin. Error bars represent 95% confidence intervals for the proportion calculated by the Clopper-Pearson exact binomial method**.**

Antimicrobial resistance in *Salmonella* isolates from dairy cattle

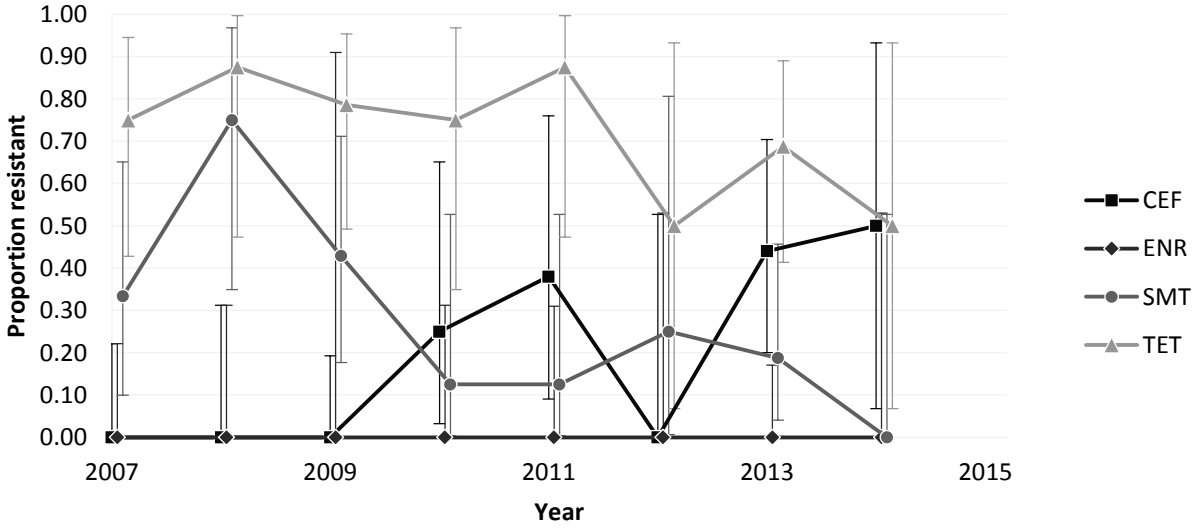

Figure 4: Proportion of *Salmonella* isolates from dairy cattle submitted to the Animal Health Centre resistant to ceftiofur (CEF), enrofloxacin (ENR), sulfa-trimethoprim (SMT) and tetracycline (TET) by year. There were no Salmonella isolated from dairy cattle in 2015. Error bars represent 95% confidence intervals for the proportion calculated by the Clopper-Pearson exact binomial method.

Commentary

There were no trends of increasing or decreasing resistance to any antimicrobial in *Salmonella* isolated from any animal type over time. There was no enrofloxacin resistance in *Salmonella* in any animal type and no resistance to sulfa-trimethoprim in isolates from poultry. In general, resistance was highest to tetracycline, followed by ceftiofur.

Antimicrobial Resistance in *Escherichia coli*

Background

E. coli are normal flora in the gastrointestinal tract of animals and humans, but can also act as disease causing agents in animals and people. *E. coli* from animals can be transmitted to people through handling or ingestion of animal-origin foods, and contaminated plant-origin foods, as well as through direct contact with animals.

Resistance monitoring in *E.coli* is included in most antimicrobial resistance monitoring programs, including CIPARS. CIPARS uses active sampling to monitor antimicrobial resistance in *E.coli* isolated from farms, abattoirs and retail meat from beef cattle, broiler chickens, pigs, and turkeys.

Between January 1, 2007 and December 31, 2015, *E. coli* were the most frequently isolated bacteria from submissions to the AHC. At the AHC, four different antimicrobial panels for antimicrobial resistance testing of *E. coli* are in use: mammalian gram-negative, avian gram-negative, porcine, and milk. Ceftiofur, sulfa-trimethoprim and tetracycline are common to all four panels and each represents a different antimicrobial class. Enrofloxacin, a fluoroquinolone, is common to the mammalian gram-negative and avian gram-negative panels, but is not included in the porcine or milk panels. In Canada, ceftiofur and enrofloxacin are classified as 'very high importance' to human medicine, while sulfa-trimethoprim is classified as 'high importance' and tetracycline is classified as 'medium importance' (Health Canada, 2009).

In this section of the report, results are presented as tables showing resistance in *E. coli* isolates to ceftiofur, enrofloxacin, sulfa-trimethoprim and tetracycline by animal type. This is followed by graphs of proportion of resistant isolates (with 95% confidence intervals) by animal types for meat-type chickens (broilers and broiler-breeders), layer chickens, turkeys, pigs, dairy cattle and beef cattle. These animal types were chosen because there were a sufficient number of isolates to present data graphically.

Results

Seven-thousand one-hundred and fifty-eight *E. coli* isolates, originating from 4,878 cases, were tested for antimicrobial resistance between January 1, 2007 and December 31, 2015. Of these, 5,801 were from animal tissues, 664 were from fecal samples, 246 were from milk samples from dairy cattle of dairy goats, 14 were from environmental swabs and two were from feed samples. The site of origin for four hundred and thirty-one isolates from swabs submitted by veterinarians could not be determined. A mean of 732 isolates were tested per year with a minimum of 473 isolates (2007) and a maximum of 957 isolates (2015) tested in one year.

Table 9: Origin of *E. coli* isolates screened for antimicrobial resistance at the AHC between January 1, 2007 and December 31, 2015.

Animal Type[a]	Total Isolates	Isolates per Year		
		Minimum	Mean	Maximum
Chicken (meat-type)	2,600	96	276	458
Chicken (layer)	513	42	55	76
Turkeys	602	33	65	104
Pigs	385	18	42	56
Cattle (dairy)	920	0	93	150
Cattle (beef)	193	4	21	38
Other food animals	765	19	77	203
Companion animals	125	9	14	21
Other animals and birds	1,055	57	113	160

[a]Submissions were classified into animal type by evaluation of species and breed data. The category 'other food animals' includes sheep and goats, as well as poultry and cattle where the breed or production type was not specified. 'Companion animals' include any animal deemed to be in close contact with people, including horses. 'Other animals and birds' includes wild animals, and non-food producing domestic animals (i.e. mink).

Table 10. Proportion of *E. coli* isolates susceptible to 4 antimicrobials (ceftiofur, enrofloxacin, sulfa-trimethoprim and tetracycline) by animal type[a] and year.

	Proportion susceptible to 4 antimicrobials						Number of isolates					
	Chickens-meat type	Chickens-layers	Turkeys	Pigs[c]	Dairy cattle	Beef cattle	Chickens-meat type	Chickens-layers	Turkey	Pigs	Dairy cattle	Beef cattle
All years	.29	.31	.32	.12	.33	.40	2600	513	602	385	676[d]	193
2007	.20[b]	.31[b]	.31[b]	.05	.31	.29	96	45	39	40	50	14
2008	.33[b]	.55[b]	.44[b]	.09	.29	.07	165	42	50	35	91	15
2009	.31	.58	.38	.14	.37	.47	308	50	61	44	91	38
2010	.24	.48	.36	.21	.38	.54	180	56	33	29	55	13
2011	.37	.64	.26	.04	.36	.36	294	50	38	45	91	25
2012	.34	.56	.36	.12	.29	.42	346	62	74	49	132	38
2013	.21	.58	.32	.14	.29	.41	366	76	104	56	122	22
2014	.28	.55	.26	.13	.39	.50	272	51	100	46	44	24
2015	.26	.63	.21	.13	.45	.25	573	81	103	41	0	4

[a]Submissions were classified into animal type by evaluation of species and breed data. Poultry and cattle where the breed or production type was not specified were classified as 'other food animals' and are not included in the table.

[b]For poultry, isolates were not tested for resistance to sulfa-trimethoprim in 2007 and 2008, therefore we report the proportion susceptible to 3 antimicrobials (enrofloxacin, ceftiofur and tetracycline) for those years.

[c]For pigs, isolates were not tested for resistance to enrofloxacin, so we report the proportion susceptible to 3 antimicrobials (ceftiofur, sulfa-trimethoprim and tetracycline).

[d]The AHC milk antimicrobial panel does not include enrofloxacin, therefore enrofloxacin resistance data was not available for 244 fluid milk samples. Six-hundred-seventy six isolates from dairy cattle from tissue other than milk were tested for resistance to enrofloxacin using the AHC gram-negative antimicrobial panel.

Table 11. Proportion of *E. coli* isolates resistant to ceftiofur by animal type[a] and year.

	Proportion resistant to ceftiofur						Number of isolates					
	Chickens-meat type	Chickens-layers	Turkeys	Pigs	Dairy cattle	Beef cattle	Chickens-meat type	Chickens-layers	Turkey	Pigs	Dairy cattle	Beef cattle
All years	.36	.14	.19	.11	.17	.06	2600	513	602	385	920	193
2007	.35	.33	.21	.15	.15	0	96	45	39	40	61	14
2008	.28	.12	.30	0	.13	.13	165	42	50	35	106	15
2009	.41	.14	.15	.05	.13	0	308	50	61	44	110	38
2010	.39	.21	.18	.10	.14	.15	180	56	33	29	71	13
2011	.31	.06	.26	.09	.15	0	294	50	38	45	111	25
2012	.35	.11	.15	.10	.18	.05	346	62	74	49	156	38
2013	.55	.16	.18	.13	.23	.13	366	76	104	56	166	22
2014	.35	.12	.14	.20	.25	.04	272	51	100	46	100	24
2015	.27	.05	.29	.25	.09	.50	573	81	103	41	39	4

[a]Submissions were classified into animal type by evaluation of species and breed data. Poultry and cattle where the breed or production type was not specified were classified as 'other food animals' and are not included in the table.

Table 12. Proportion of *E. coli* isolates resistant to enrofloxacin by animal type[a] and year.

Year	Proportion resistant					Number of isolates tested				
	Chickens-meat type	Chickens-layers	Turkeys	Dairy cattle	Beef cattle	Chickens-meat type	Chickens-layers	Turkeys	Dairy cattle[b]	Beef cattle
All years	.03	.01	.02	.10	.02	2600	513	602	676	193
2007	.02	0	0	.12	0	96	45	39	50	14
2008	.02	.02	.04	.13	0	165	42	50	91	15
2009	.01	0	0	0	0	308	50	61	91	38
2010	.04	0	.03	.05	.08	180	56	33	55	13
2011	.02	0	0	.15	0	294	50	38	91	25
2012	.02	.02	0	.11	.08	346	62	74	132	38
2013	.05	.01	.02	.11	0	366	76	104	122	22
2014	.06	0	.05	.09	0	272	51	100	44	24
2015	.04	0	.10	-	0	573	81	103	0	4

[a]Submissions were classified into animal type by evaluation of species and breed data. Poultry and cattle where the breed or production type was not specified were classified as 'other food animals' and are not included in the table. The porcine panel used at AHC for antimicrobial resistance testing does not include enrofloxacin (or other fluoroquinolones) so fluoroquinolone resistance data for pig isolates was not available.

[b]The AHC milk antimicrobial panel does not include enrofloxacin (or other fluoroquinolones), therefore enrofloxacin resistance data was not available for 244 fluid milk samples. Six-hundred-seventy six isolates from non-milk samples from dairy cattle were tested for resistance to enrofloxacin using the AHC gram-negative antimicrobial panel.

Table 13. Proportion of *E. coli* isolates resistant to sulfa-trimethoprim by animal type[a] and year.

	Proportion resistant to sulfa-trimethoprim						Number of isolates					
	Chickens-meat type	Chickens-layers	Turkeys	Pigs	Dairy cattle	Beef cattle	Chickens-meat type[b]	Chickens-layers[b]	Turkeys[b]	Pigs	Dairy cattle	Beef cattle
All years	.09	.08	.10	.27	.46	.33	2339	426	513	382	920	193
2007	-	-	-	.27	.49	.29	0	0	0	40	61	14
2008	-	-	-	.23	.50	.73	0	0	0	35	106	15
2009	.06	0	.19	.27	.40	.24	308	50	61	44	110	38
2010	.11	.04	.09	.17	.46	.23	180	56	33	29	71	13
2011	.08	.04	.03	.36	.42	.32	294	50	38	45	111	25
2012	.06	.15	.14	.24	.48	.39	346	62	74	49	156	38
2013	.11	.12	.07	.23	.51	.23	366	76	104	56	166	22
2014	.09	.02	.11	.35	.38	.29	272	51	100	46	100	24
2015	.11	.03	.09	.28	.11	.50	573	81	103	41	39	4

[a]Submissions were classified into animal type by evaluation of species and breed data. Poultry and cattle where the breed or production type was not specified were classified as 'other food animals' and are not included in the table.

[b]The AHC began testing gram-negative bacterial isolated from poultry for resistance to sulfa-trimethoprim began in mid-2009.

Table 14. Proportion of *E. coli* isolates resistant to tetracycline by animal type[a] and year.

	Proportion resistant to tetracycline						Number of isolates					
	Chickens-meat type	Chickens-layers	Turkeys	Pigs	Dairy cattle	Beef cattle	Chickens-meat type	Chickens-layers	Turkeys	Pigs	Dairy cattle	Beef cattle
All years	.55	.39	.65	.85	.63	.58	2600	491	581	382	920	193
2007	.63	.60	.67	.95	.69	.64	96	45	39	40	61	14
2008	.55	.40	.52	.86	.67	.93	165	42	50	35	106	15
2009	.49	.36	.62	.86	.60	.53	308	50	61	44	110	38
2010	.56	.50	.61	.65	.59	.46	180	56	33	29	71	13
2011	.50	.32	.63	.96	.57	.52	294	50	38	45	111	25
2012	.62	.34	.62	.86	.67	.58	346	62	74	49	156	38
2013	.55	.29	.65	.82	.63	.55	366	76	104	56	166	22
2014	.59	.37	.71	.82	.56	.50	272	51	100	46	100	24
2015	.61	.34	.77	.87	.49	.75	573	81	103	41	39	4

[a]Submissions were classified into animal type by evaluation of species and breed data. Poultry and cattle where the breed or production type was not specified were classified as 'other food animals' and are not included in the table.

Antimicrobial resistance in *E. coli* isolates from meat-type chickens

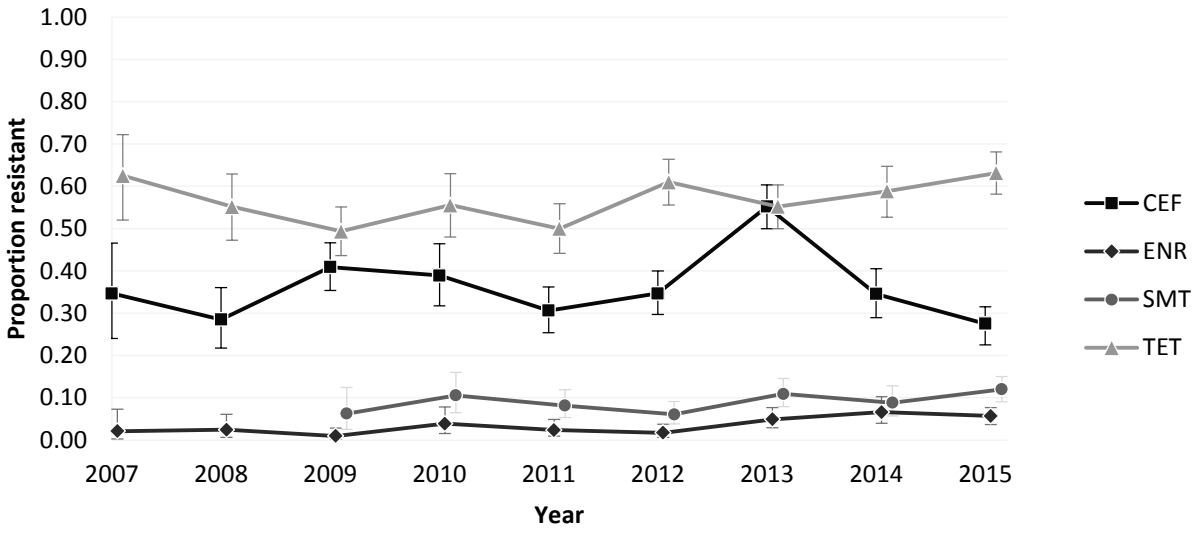

Figure 5: Proportion of *E. coli* isolates from meat-type chickens submitted to the Animal Health Centre resistant to ceftiofur (CEF), enrofloxacin (ENR), sulfa-trimethoprim (SMT) and tetracycline (TET) by year. Error bars represent 95% confidence intervals for the proportion calculated by the Clopper-Pearson exact binomial method.

Antimicrobial resistance in *E.coli* isolates from layer chickens

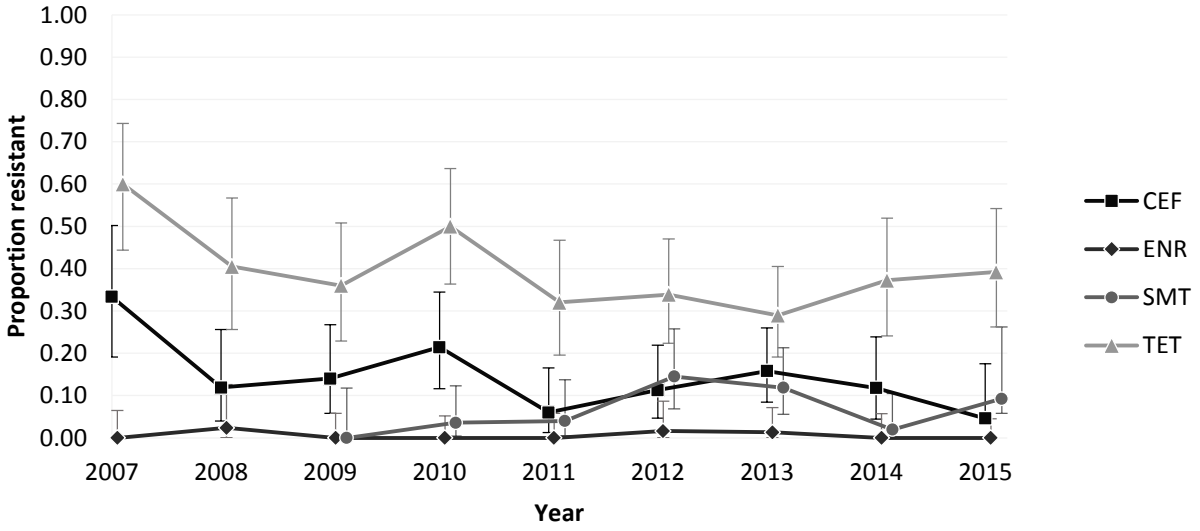

Figure 6: Proportion of *E. coli* isolates from layer chickens submitted to the Animal Health Centre resistant to ceftiofur (CEF), enrofloxacin (ENR), sulfa-trimethoprim (SMT) and tetracycline (TET) by year. Error bars represent 95% confidence intervals for the proportion calculated by the Clopper-Pearson exact binomial method.

Antimicrobial resistance in *E.coli* isolates from turkeys

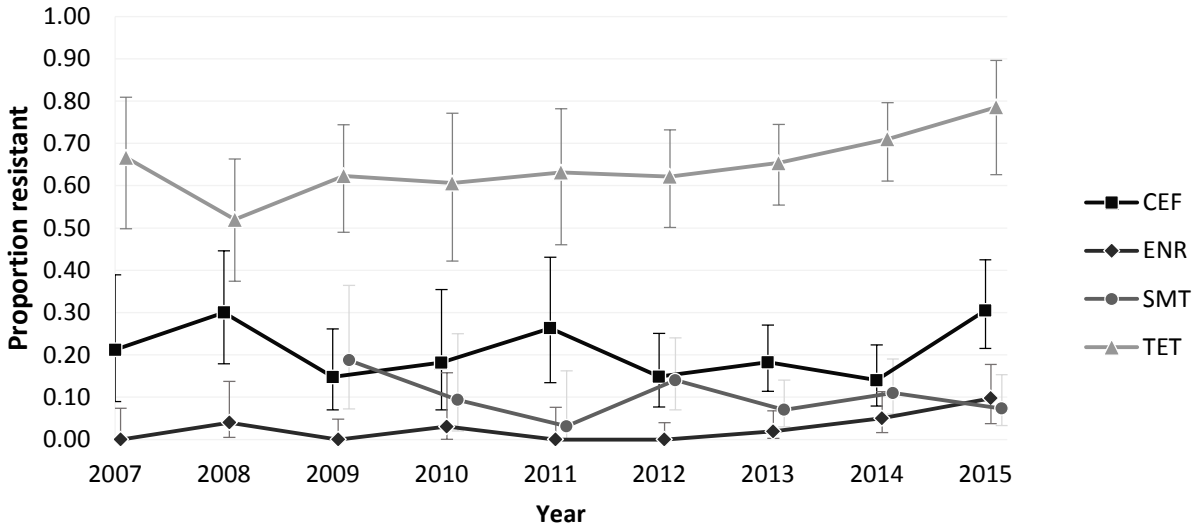

Figure 7: Proportion of *E. coli* isolates from turkeys submitted to the Animal Health Centre resistant to ceftiofur (CEF), enrofloxacin (ENR), sulfa-trimethoprim (SMT) and tetracycline (TET) by year. Error bars represent 95% confidence intervals for the proportion calculated by the Clopper-Pearson exact binomial method.

Antimicrobial resistance in *E.coli* isolates from pigs

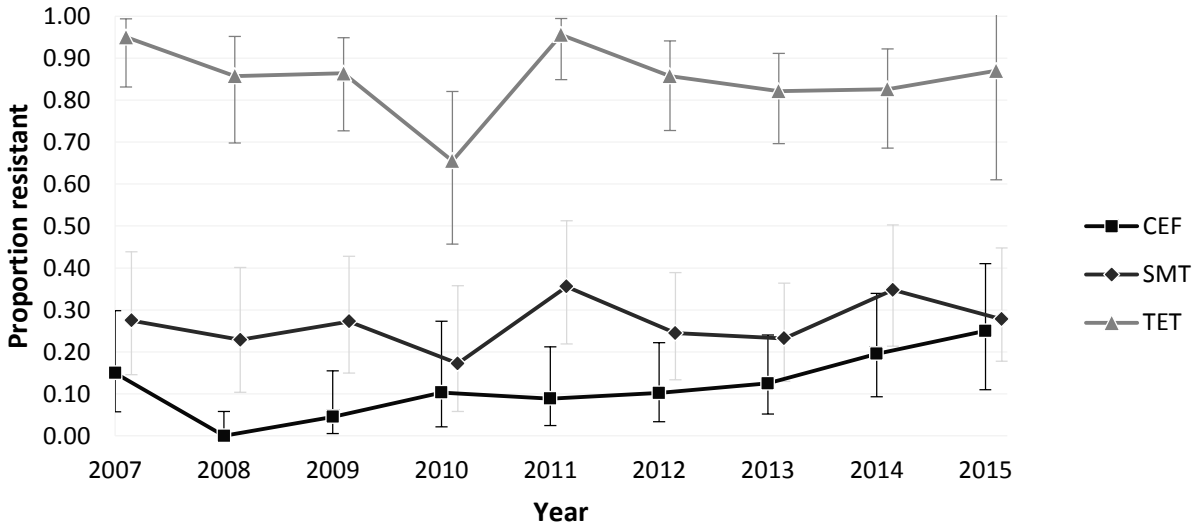

Figure 8: Proportion of *E. coli* isolates from pigs submitted to the Animal Health Centre resistant to ceftiofur (CEF), sulfa-trimethoprim (SMT) and tetracycline (TET) by year. Pig isolates were not tested for resistance to enrofloxacin. Error bars represent 95% confidence intervals for the proportion calculated by the Clopper-Pearson exact binomial method.

Antimicrobial resistance in *E.coli* isolates from dairy cattle

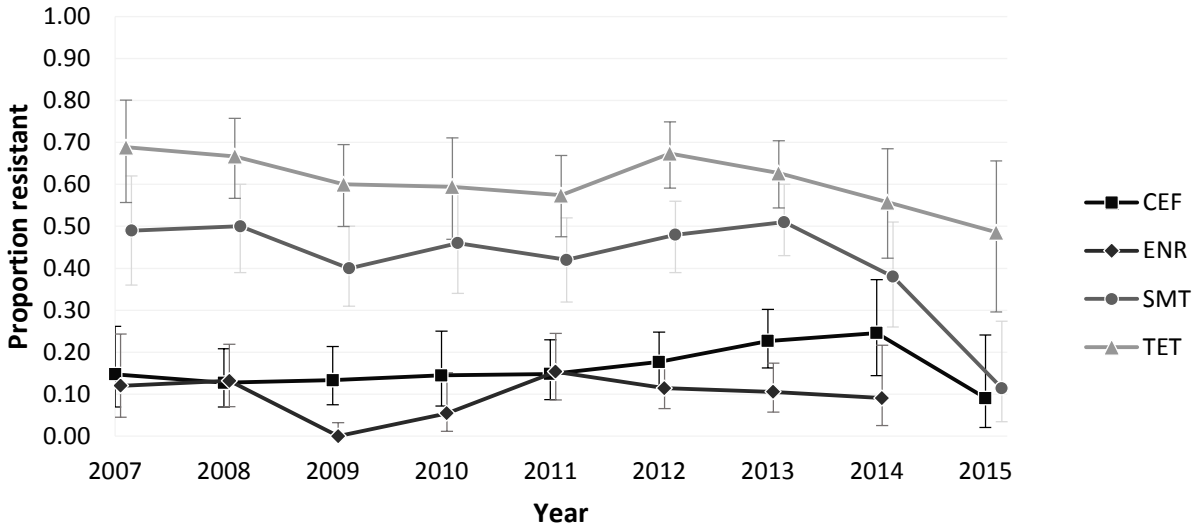

Figure 9: Proportion of *E. coli* isolates from dairy cattle submitted to the Animal Health Centre resistant to ceftiofur (CEF), enrofloxacin (ENR), sulfa-trimethoprim (SMT) and tetracycline (TET) by year. Error bars represent 95% confidence intervals for the proportion calculated by the Clopper-Pearson exact binomial method. The AHC AMR Milk Panel does not include enrofloxacin (or other fluoroquinolones), therefore enrofloxacin resistance data was not available for 244 fluid milk samples, including all 44 isolates from 2015. Therefore, 676 isolates from non-milk samples from dairy cattle are represented in the graph.

Antimicrobial resistance in *E.coli* isolates from beef cattle

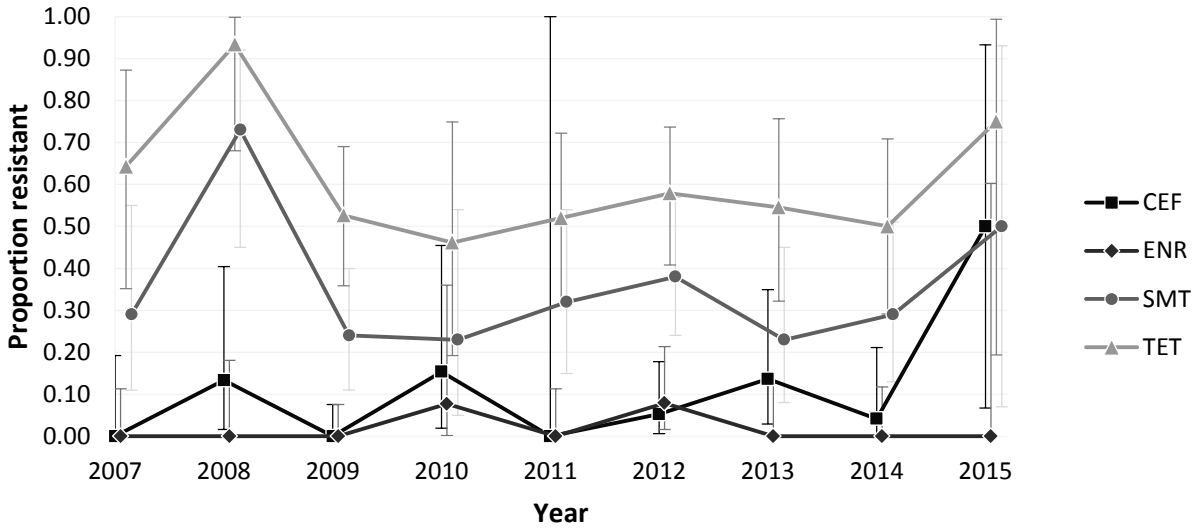

Figure 10: Proportion of *E. coli* isolates from beef cattle submitted to the Animal Health Centre resistant to ceftiofur (CEF), enrofloxacin (ENR), sulfa-trimethoprim (SMT) and tetracycline (TET) by year. Error bars represent 95% confidence intervals for the proportion calculated by the Clopper-Pearson exact binomial method.

Commentary

There were no trends of increasing or decreasing resistance to any antimicrobial in *E. coli* isolated from any animal type over time. In all animal types, isolates of *E. coli* showed lowest resistance to enrofloxacin and highest resistance to tetracycline. Resistance to sulfa-trimethoprim and ceftiofur was intermediate and differed somewhat between animal types, with poultry showing comparatively higher resistance to ceftiofur, while cattle and pigs showed higher resistance to sulfa-trimethoprim.

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