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Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS)

Annual Report

To promote and protect the health of Canadians through leadership, partnership, innovation and action in public health, Public Health Agency of Canada

Working towards the preservation of effective antimicrobials for humans and animals, Canadian Integrated Program for Antimicrobial Resistance Surveillance

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To obtain additional information, please contact:

Public Health Agency of Canada

Address Locator 0900C2

Ottawa, ON K1A 0K9

Tel.: 613-957-2991

Toll free: 1-866-225-0709

Fax: 613-941-5366

Teletypewriter: 1-800-465-7735

E-mail: publications@hc-sc.gc.ca

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Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS)

2016 Annual Report

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Executive summary

The Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS) collects, analyses, and communicates trends in antimicrobial use and in antimicrobial resistance for select bacteria from humans, animals, and retail meat across Canada. The bacteria under surveillance are known as enteric bacteria (can be found in the intestines of people and animals) and can be transmitted between animals and people. Information from CIPARS supports measures to contain the emergence and spread of resistant bacteria among animals, food, and people, with the aim of prolonging the effectiveness of antimicrobials.

The overall quantity of antimicrobials intended for use in Canadian animals was lower in 2016 than in 2015. However in broiler chickens, while the quantity of antimicrobials used was lower, the number of doses per kg chicken or doses per bird increased in 2016. This means that the decrease in quantity of antimicrobials used was attained by switching antimicrobial products and demonstrates the importance of using different methods of analysing antimicrobial use data to provide a more complete understanding of trends over time. Antimicrobial use data from several sources (i.e., the Canadian Animal Health Institute, CIPARS sentinel farms, IQVIA human data) showed that the types of antimicrobials used differed substantially between people and animals and between different animal species. Surveillance of antimicrobial use and resistance on turkey farms has recently been added to CIPARS; this report includes our first information from these farms. For broiler chickens, turkeys, and grower-finisher pigs, sentinel farm data showed that the majority of antimicrobials were administered for the purpose of disease prevention rather than for treatment of disease or growth promotion. For broiler chickens and grower-finisher pigs, sentinel farm data also showed that the use of medically important antimicrobials for growth promotion purposes declined in 2016. Reduction in reported antimicrobial use for growth promotion in broiler chickens is believed to be due to anticipatory changes by the industry ahead of expected federal policy changes.

With respect to multidrug resistance, the number of human and agri-food *Salmonella* isolates resistant to more than 5 antimicrobial classes continued to increase in 2016, particularly in isolates from humans, cattle, and pigs. In 2016, there were no isolates from chickens or turkeys that were resistant to more than 5 antimicrobial classes.

There are ongoing regional differences in the level of fluoroquinolone resistance in *Campylobacter* from chickens and chicken meat. For the first time, we were able to report limited human data for 3 regions of Canada; resistance to ciprofloxacin was more commonly identified in human *Campylobacter* isolates from British Columbia and Alberta, than from Ontario.

The poultry industry-led initiative to eliminate use of ceftiofur and all other antimicrobials of very high importance to human medicine for disease prevention appears to have had the desired effect. Our data showed no reported use of ceftiofur since 2014 in broiler chickens and declining levels of ceftriaxone resistance in both *Escherichia coli* and *Salmonella* from chickens and chicken meat. However, it appears that ceftiofur use in chickens was replaced with the use of other antimicrobials, such as gentamicin and lincomycin-spectinomycin. Subsequently, CIPARS has observed increasing resistance to gentamicin in *Salmonella* and *E. coli* from chickens and chicken meat. The poultry industry in Canada has committed to removing the preventive use of antimicrobials of high importance to human medicine by the

end of 2018 (which will include gentamicin and lincomycin-spectinomycin), and has set a goal to eliminate the preventive use of antimicrobials of medium importance to human medicine by the end of 2020.

CIPARS will continue to monitor and communicate the impact of changing use practices on the occurrence of resistance in animals and humans. CIPARS analysts are working to develop new ways of identifying emerging issues and integrating data across various host species, bacterial species and across regions. Key CIPARS findings for 2016 were also included in the 2017 Canadian Antimicrobial Resistance Surveillance System Report.

Contributors to CIPARS

Program coordinators in 2016

Rebecca Irwin[1], Richard Reid-Smith[1], and Michael Mulvey[2]

Surveillance component leads

- Surveillance of Human Clinical Isolates: Brent Avery, Michael Mulvey, Jane Parmley
- Retail Meat Surveillance: Brent Avery
- Abattoir Surveillance: Anne Deckert
- Farm Surveillance: Agnes Agunos, Anne Deckert, Sheryl Gow, and David Léger
- Surveillance of Animal Clinical Isolates: Jane Parmley
- Quantities of Antimicrobials Distributed for Sale for Use in Animals and Plants: Carolee Carson

Antimicrobial resistance data management and analysis leads

Brent Avery and Jane Parmley

Antimicrobial use data management and analysis leads

Agnes Agunos, Carolee Carson, Anne Deckert, Sheryl Gow, and David Léger

Authors/analysts

Antimicrobial resistance

Agnes Agunos, Brent Avery, Anne Deckert, Sheryl Gow, and Jane Parmley

Antimicrobial use

Agnes Agunos, Carolee Carson, Anne Deckert, Sheryl Gow, and David Léger

Report production

Michelle Tessier and Virginia Young

Laboratory component leads

National Microbiology Laboratory @ Winnipeg

- Reference Services Unit: Sara Christianson
- Antimicrobial Susceptibility Testing: Michael Mulvey

[1] Centre for Food-borne, Environmental and Zoonotic Infectious Diseases, Public Health Agency of Canada (PHAC).

[2] National Microbiology Laboratory, Winnipeg, PHAC.

National Microbiology Laboratory @ Guelph

- *Salmonella* Typing: Bob Holtslander and Gitanjali Arya
- Antimicrobial Susceptibility Testing: Andrea Desruisseau and Chad Gill

National Microbiology Laboratory @ Saint-Hyacinthe

- Antimicrobial Susceptibility Testing: Danielle Daignault, Manon Caron, and Sophia Sheriff
- Primary Isolation: Louise Beausoleil, Sindy Cleary, Marie-Claude Deshaies, Maxime Gosselin-Théberge, and Julie Roy

Provincial public health laboratories

We gratefully acknowledge the provincial public health laboratories for their longstanding support and for providing data and bacterial isolates for CIPARS:

- British Columbia Public Health Microbiology and Reference Laboratory, Provincial Health Services Authority, British Columbia (Linda Hoang)
- Provincial Laboratory for Public Health, Alberta (Marie Louie)
- Saskatchewan Laboratory and Disease Control Services (Greg Horsman)
- Cadham Provincial Laboratory, Manitoba (John Wylie)
- Public Health Ontario Laboratory, Public Health Ontario (Vanessa Allen)
- Laboratoire de santé publique du Québec de l'Institut national de santé publique du Québec (Sadjia Bekal)
- New Brunswick Enteric Reference Centre (Sameh El Bailey)
- Microbiology Laboratory, Queen Elizabeth II Health Sciences Centre, Nova Scotia (David Haldane)
- Laboratory Services, Queen Elizabeth Hospital, Prince Edward Island (Greg German)
- Newfoundland Public Health Laboratory (George Zahariadis)

Retail meat surveillance

We would like to extend our thanks to the following organizations for their participation in CIPARS Retail Meat Surveillance:

- Centre for Coastal Health (Carl Ribble and Stefan Iwasawa)
- Agriculture and Agri-Food Canada (Mueen Aslam, Tineke Jones, Cara Service, and Tim McAllister)

We also thank the following health unit managers, public health inspectors, and environmental health officers: Bob Bell, Tanya Musgrave, Torsten Schulz, and Lee Siewerda.

Abattoir surveillance

We would like to thank the abattoir operators and the Canadian Food Inspection Agency's regional directors, inspection managers, and on-site staff, for their extensive voluntary participation in CIPARS Abattoir Surveillance.

Farm surveillance

We are grateful for the support of the Alberta Agriculture and Forestry, the Canadian Poultry Research Council, the Ontario Ministry of Agriculture, Food and Rural Affairs, and the Saskatchewan Ministry of Agriculture, as well as the sentinel veterinarians and the producers who participated in Farm Surveillance by providing data and enabling collection of samples for bacterial culture.

We would like to acknowledge the following organizations for their contribution to the CIPARS Farm Surveillance components:

- Alberta Chicken Producers
- British Columbia Chicken Marketing Board
- British Columbia Turkey Farmers
- Canadian Hatcheries Federation
- Canadian Pork Council and Provincial Pork Boards
- Canadian Poultry and Egg Processors Council
- Chicken Farmers of Canada
- Chicken Farmers of Ontario
- CIPARS Farm Broiler Chicken Industry Antimicrobial Use/Resistance Working Group
- CIPARS Farm Swine Advisory Committees
- Les Éleveurs de volailles du Québec
- Turkey Farmers of Ontario
- Turkey Farmers of Canada

Provincial animal health laboratories

We gratefully acknowledge the provincial animal health laboratories for their longstanding support and for providing data and bacterial isolates for CIPARS:

- Animal Health Centre, British Columbia Ministry of Agriculture (Nancy DeWith and Erin Zabek)
- Government of Alberta, Agriculture and Forestry (Rashed Cassis)
- Saskatchewan Health, Saskatchewan (Paul Levett)
- Veterinary Services Branch Laboratory, Manitoba (Neil Pople)
- The Animal Health Laboratory, University of Guelph, Ontario (Durda Slavic)
- IDEXX Laboratories, Ontario (Hani Dick)
- Direction générale des laboratoires d'expertise du ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (Marie Nadeau)
- Laboratoire d'épidémiosurveillance animale du Québec (Olivia Labrecque)
- Provincial Veterinary Laboratory, Department of Agriculture, Fisheries, and Aquaculture, New Brunswick (Jim Goltz)
- Veterinary Pathology Laboratory, Nova Scotia (Grant J. Spearman)
- Diagnostic Services, Atlantic Veterinary College, Prince Edward Island (Jan Giles)
- Animal Health Laboratory, Department of Fisheries, Forestry and Agrifoods, Newfoundland and Labrador (Laura Rogers)

Quantities of antimicrobials distributed for sale for use in animals

We would like to sincerely thank the Canadian Animal Health Institute (CAHI), its President Jean Szkotnicki and their member companies for voluntarily providing the quantities of antimicrobials distributed for sale for use in animals in Canada. We would also like to thank Impact Vet for collating the data.

CIPARS would like to thank the University of Guelph (Dr. Scott McEwen) for the joint collaborations with multiple students who have assisted in the preparation of the population correction unit: Ashley Gagne, Victoria Wells, Sarah Garner, Angela Bosman, and Daleen Loest. CIPARS would also like to thank Christian Klopfenstein for his excellent review and input to appropriate weights for the Canadian denominator.

CIPARS thanks the European Surveillance for Veterinary Antimicrobial Consumption, the Food and Drug Administration's Center for Veterinary Medicine of the United States, and the World Organization for Animal Health (OIE) for many long discussions on appropriate denominators for antimicrobial sales/distribution data.

Other participants

We gratefully acknowledge the efforts of field workers, laboratory technicians, and data managers for their contributions. The careful collection of samples, processing of isolates, and recording of results are essential to the ongoing success of CIPARS.

We are grateful to the National Antimicrobial Resistance Monitoring System of the United States for sharing information and facilitating harmonization with CIPARS.

We would also like to thank the following individuals and organizations for their contribution to CIPARS in 2016:

Public Health Agency of Canada

Ashleigh Andrysiak, Louise Bellai, Mark Blenkinsop, Gail Christie, Sindy Cleary, Ann-Marie Cochrane, Marie-Claude Deshaies, Logan Flockhart, George Golding, Dolly Kambo, Nicol Janecko, Jasmina Kircanski, Ora Kendall, Lisa Landry, Stacie Langner, Julie Légaré, Laura Martin, Sarah Martz, Ryan McKarron, Ketna Mistry, Ali Moterassed, Manuel Navas, Linda Nedd-Gbedemah, Derek Ozunk, Ann Perets, Frank Pollari, Susan Read, Julie Roy, Sophia Sheriff, Lien Mi Tien, Rama Viswanathan, Victoria Weaver, and Betty Wilkie.

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Canadian Food Inspection Agency

Daniel Leclair, Blaise Ouattara, and Marina Steele

Health Canada, Veterinary Drugs Directorate

Xian-Zhi Li and Manisha Mehrotra

Health Canada, Pest Management Regulatory Agency

Brian Belliveau

Canadian Meat Council

Independent contractors

John Ranson and Ron Templeman

Program overview

About CIPARS

The Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS), created in 2002, is a national program dedicated to the collection, integration, analysis, and communication of trends in antimicrobial use (AMU) and resistance (AMR) in selected bacteria from humans, animals, and animal-derived food sources across Canada. This information supports (i) the creation of evidence-based policies for AMU in hospitals, communities, and food-animal production with the aim of prolonging the effectiveness of these drugs and (ii) the identification of appropriate measures to contain the emergence and spread of resistant bacteria among animals, food, and people.

CIPARS continues to evolve to meet stakeholder needs. To enhance the timeliness of reporting, between 2012 and 2014 CIPARS piloted the division of the annual report into separate chapters, with chapters being posted as they were completed. This reporting method did not result in efficiency and CIPARS has returned to the release of a single Annual Report. For 2016, integrated findings have been published in the 2017 Canadian Antimicrobial Resistance Surveillance System Report.

CIPARS objectives

- Provide a unified approach to monitor trends in antimicrobial resistance and antimicrobial use in humans and animals.
- Facilitate assessment of the public health impact of antimicrobials used in humans and agricultural sectors.
- Allow accurate comparisons with data from other countries that use similar surveillance systems.

What's new

Antimicrobial resistance

- For 2016, due to limited sampling technician availability, only a partial year's worth of retail sampling was conducted in Ontario and the Prairies. Sampling target and isolate yields were therefore not achieved. Additionally in 2016, retail sampling activities in the Atlantic region were suspended due to budgetary constraints.
- *Campylobacter* spp. was not isolated from retail ground turkey samples in 2016.
- The CIPARS Farm Surveillance turkey component was initiated in 2016 in the 3 major poultry-producing provinces in Canada (British Columbia, Ontario, and Québec). Additionally, the Farm Surveillance feedlot beef component was also initiated in 2016. Sampling is currently only being done in the Alberta FoodNet Canada site.

- In 2016, in addition to traditional phenotypic serotyping method serotyping, a portion of the CIPARS isolates were tested using a DNA microarray-based alternative method called the *Salmonella* GenoSerotyping Array (SGSA).
- A new NARMS antimicrobial susceptibility testing plate CMV4AGNF was used for 2016. Notable differences are the removal of ceftiofur and addition of meropenem (Category I) to the testing panel, as well as the changing of testing dilution range to azithromycin from 0.25 to 32 µg/mL and adopting the new breakpoint of greater than or equal to 32 µg/mL as compared to the previous value of greater than or equal to 64 µg/mL.

Antimicrobial use in animals

- In 2016, antimicrobial use data was collected from turkey flocks in British Columbia, Ontario, and Québec.
- Via the Canadian Antimicrobial Resistance Surveillance System (CARSS; personal communication), the kg of active ingredient dispensed by community pharmacies and purchased by hospitals was accessed in 2016 allowing for the kg of antimicrobials intended for human use to be compared with the kg distributed for use in animals and sold for use as pesticides on food crops.
- In 2016, the quantitative antimicrobial use metrics, number of Canadian Defined Daily Doses for animals per 1,000 animal-days (nDDDvetCA/1,000 animal-days) was adapted to include “days at risk”.

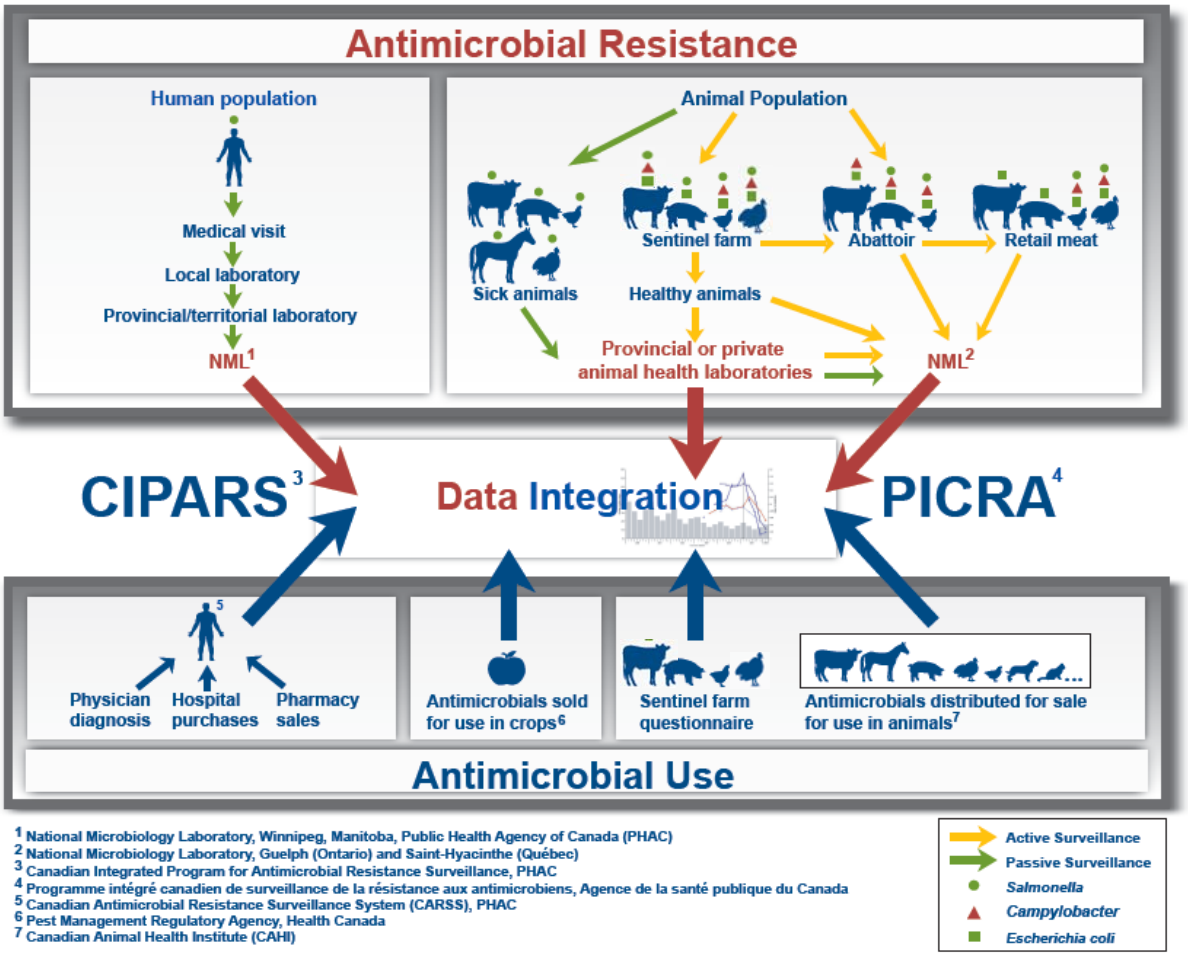
Chapter 1 Integrated findings and discussion

How to read this chapter

This chapter integrates CIPARS data collected from different sources and settings (Figure 1. 1). The strength of CIPARS lies not only in detecting emerging trends and issues in each sector individually, but also in bringing together diverse sources of data in a robust and sound manner. There are many different ways to integrate data; we have selected the most relevant and important findings that span one or more CIPARS components.

New in 2016, CIPARS collected and integrated antimicrobial resistance data from feedlot beef and turkey farms, as well as antimicrobial use data from turkeys on farm. Further details about individual CIPARS components, detailed regional and sector specific trends can be found in the chapter on antimicrobial use, the chapter on antimicrobial resistance, as well as the methods chapter.

Figure 1. 1 Diagram of CIPARS surveillance components in 2016



Data integration

To identify key stories arising from the 2016 surveillance year, the CIPARS analysis team closely examined data from all individual surveillance components. Select findings included in this chapter involve "common themes" that span multiple surveillance components and/or host species (including humans). In this chapter, the term "agri-food" refers to all non-human CIPARS components.

The antimicrobial resistance integration focuses primarily on antimicrobials of very high importance to human medicine (Category I[3]) and those isolates that are resistant to more than 5 different antimicrobial classes. When integrating antimicrobial use and resistance data, other medically important categories of antimicrobials are also considered.

Data sources

Most of the data presented in this chapter are described and reported in other chapters of this report, with the exception of kg of active ingredient of antimicrobials reported being used in humans and plants. Human antimicrobial use data are provided to CIPARS by IQVIA via the Canadian Antimicrobial Resistance Surveillance System (CARSS) and consist of quantities dispensed by community pharmacies and purchased by hospitals. The quantities of antimicrobials sold for use as pesticides on crops are provided by Health Canada's Pest Management Regulatory Agency.

Where appropriate, additional data from CIPARS research projects and collaborations are incorporated into the integrated stories.

[3] Category I antimicrobials are classified by Health Canada to be of very high importance to human medicine. Available at: https://www.canada.ca/en/health-canada/services/drugs-health-products/veterinary-drugs/antimicrobial-resistance/categorization-antimicrobial-drugs-based-importance-human-medicine.html. Accessed July 2018.

Summary of integrated findings and discussion

Integrated findings span host species (humans, chickens, pigs, beef cattle, and turkeys), surveillance components (clinical human, farm, abattoir [slaughterhouse], retail meat, and clinical animals], antimicrobial resistance and antimicrobial use, or a combination of these. The integrated findings included in this chapter are selected from those presented at the annual CIPARS stakeholder meeting on November 15, 2017. Where appropriate, we have incorporated and addressed comments and questions raised by the CIPARS stakeholder meeting participants. Integrated findings presented at the CIPARS stakeholder meeting, but not included in this chapter may be included in peer-reviewed publications and/or updated at future CIPARS stakeholder meetings.

The following is a summary of the 2016 integrated findings.

Integrate antimicrobial use data

- Overall, antimicrobial use was lower in 2016 than in 2015.
    - However, in broiler chickens, the number of daily doses per kg chicken or per bird increased between 2015 and 2016.
- Applying multiple antimicrobial use metrics provides a more complete picture of antimicrobial use trends over time and between host species.
- Each animal or host species had a different spectrum of antimicrobials that were used.
- Based on sentinel farm data, antimicrobial use in turkeys was generally lower than antimicrobial use in broiler chickens, regardless of how antimicrobial use was measured.
- Among the animal species we survey at the farm, the use of medically important antimicrobials for growth promotion has declined.
    - Reduction in reported antimicrobial use for growth promotion on broiler chicken farms may be due to industry responding to new policy requirements for removal of growth promotion claims on all medically important antimicrobials.

Integrated antimicrobial resistance data

- Since 2011, we have observed an increasing number of human and agri-food isolates resistant to more than 5 antimicrobial classes.

Integrate antimicrobial use and resistance data

- The frequency of fluoroquinolone resistance in *Campylobacter* from chicken is changing:
    - There are ongoing regional differences in the prevalence of fluoroquinolone-resistant *Campylobacter* from chicken and chicken meat. For the first time in 2016, we were able to report human *Campylobacter* data from 2 sentinel sites captured by FoodNet Canada (Alberta and Ontario). Resistance to ciprofloxacin was more commonly identified in human *Campylobacter* isolates from British Columbia and Alberta, than from Ontario.

- The poultry industry-led initiative to eliminate use of Category I antimicrobials (including the 3rd generation cephalosporin ceftiofur) in poultry for disease prevention appears to have had the desired effect to reduce AMR:
    - Data show a reduction in reported use of ceftiofur in broiler chickens and a concomitant reduction in resistance in both *E. coli* and *Salmonella* recovered from chickens on farm and at slaughter and in chicken meat at retail.
    - Use of Category II antimicrobials, including gentamicin and lincomycin-spectinomycin, has increased. CIPARS observed increasing resistance to gentamicin in *Salmonella* and *E. coli* from chickens on farm and at slaughter and in chicken meat at retail.

Note: The poultry industry in Canada has committed to removing the preventive use of Category II antimicrobials by the end of 2018 and has set a goal to eliminate the preventive use of Category III antimicrobials by the end of 2020.

Integrated findings and discussion

Integrated antimicrobial use data

In this section, we have integrated antimicrobial use (AMU) data in several ways: 1) across different sectors or host species (inter-sectoral comparisons) and 2) within 1 species or sector (intra-sectoral comparisons).

In 2016, the Category IV antimicrobials (ionophores and chemical coccidiostats) were removed from the integrated AMU section, excluding them from all of the statistics, figures and tables, presented in this chapter. This change was made to simplify communication of integrated findings and comparisons between sectors. The exclusion of these drugs also follows international reporting requirements as per the World Organisation for Animal Health (OIE)'s global database on antimicrobial agents intended for use in animals[4]. CIPARS stakeholders have also requested this change. However, information about what other drugs and products are used on farm as well as farm management and biosecurity practices provides important contextual knowledge that contributes to our general understanding of the complexities of AMU and AMR. Therefore, information about ionophore and chemical coccidiostat use in 2016 is still included in the AMU chapter of this report.

Why different antimicrobial use metrics are used

Antimicrobial use reporting is not as simple as antimicrobial resistance reporting. There are several different ways to collect, analyze, and report AMU data. No single approach is appropriate for all purposes. For example, one approach (metric[5]) might be better suited to looking at trends over time, another might be more appropriate for comparing different regions or different host species, and yet another might be better for understanding relationships between use and resistance. More than 1 metric is needed to truly understand antimicrobial use.

The methods chapter of this report includes details about how each of the different metrics was calculated. In this integrated section, we introduce some of the metrics we used and our reasons why.

From the farm component, we report the total number (or percent) of farms that reported using a particular antimicrobial. This metric provides an indication of how common or how extensive the use of a particular drug was. Using the data of farms reporting a particular antimicrobial use, we also estimate the percent of animals on the farm exposed to that antimicrobial. This metric tells us how intensive the use practice was on the farm, if that antimicrobial was used.

[4] For more information: http://www.oie.int/our-scientific-expertise/veterinary-products/antimicrobials/

[5] For reporting data on antimicrobial agents used in animals, we use different "metrics" or ways of reporting the information. When we refer to a "technical unit of measurement" we are generally referring to values often considered part of a numerator of a ratio. When we combine a technical unit of measurement with a denominator, we call these "indicators". Both technical units of measurement and indicators are metrics used to report antimicrobial use. CIPARS is evolving to use the most appropriate terminology to describe these terms; balancing ease of communication with proposed international terminology.

Total kilograms of antimicrobials is a quantitative unit of measurement that provides an indication of the overall selection pressure. However, 1 kg of an antimicrobial (A) may not equal 1 kg of another antimicrobial (B) in terms of their therapeutic effect or selection pressure. In other words, more of one antimicrobial may be required on a daily basis than another to achieve a similar effect. However, a kilogram of 1 antimicrobial may not equal a kilogram of another antimicrobial in terms of therapeutic effect or selection pressure. In other words, more of one antimicrobial might be needed on a daily basis than another to achieve the desired effect. This is a significant factor we need to consider to appropriately evaluate trends in antimicrobial use over time. Thus, to account for this, we report our data as the number (n) of Defined Daily Doses vets (DDDvet) using Canadian (CA) standards (nDDDvetCA). To further explain this, we consider a dose to be the amount of antimicrobial administered at one time, whereas the Defined Daily Dose is the total quantity of antimicrobial active ingredient administered over a 24 hour period according to what is written on the product label. However, for several antimicrobials, there is more than one marketed product resulting in several different Canadian labelled doses. In these cases, we averaged the unique Canadian labelled doses (excluding any growth promotion doses) and this average became the Defined Daily Dose (DDDvetCA). For presentation of results, we use the total kilograms of active ingredient reported being used and divide this number by the DDDvetCA to tell us how many of these daily doses were used [(nDDDvetCA = (kilograms of antimicrobials reported/DDDvetCA)].

The concept of defined daily doses was not developed by CIPARS; it has been used for reporting human AMU for many years. For human medicine, this unit of measurement is called the Defined Daily Dose (DDD) and these standards are maintained by the World Health Organisation Collaborating Centre for Drug Statistics Methodology[6]. Recently, the development and application of this concept for reporting AMU in animals has achieved consensus among European countries. The European Medicines Agency developed a guideline entitled “Principles on assignment of Defined Daily Dose for animals (DDDvet) and defined course dose for animals (DCDvet)”[7]. This guidance document was used to develop the DDDvetCA, with minor methodological modifications for the Canadian situation. We intend to publish the Canadian methods to develop the DDDvetCA.

The number of DDDvetCA is a numerator; hence a technical unit of measurement. To provide necessary context for this metric, as well as for the kilograms of active ingredient metric, we need a denominator to indicate the number of animals or number of different types of animals that were at risk of being exposed to the antimicrobial(s). Denominators are required for analysis of temporal trends, regional comparisons, and inter-sectoral comparisons. Some livestock species are more numerous than others and they are not all the same size (i.e., there are many more chickens than pigs in Canada in a given year and a pig is bigger than a chicken). To address this disparity, a common denominator to report the animal population is estimated in terms of its biomass and is applied as the denominator for reporting a measure

[6] World Health Organisation Collaborating Centre for Drug Statistics Methodology. Definitions and general considerations. Available at: https://www.whocc.no/ddd/definition_and_general_considera/. Accessed June 2018.

[7] European Surveillance of Veterinary Antimicrobial Consumption (ESVAC). Available at: http://www.ema.europa.eu/ema/index.jsp?curl=pages/regulation/document_listing/document_listing_000302.jsp. Accessed June 2018.

of AMU (e.g. milligrams) per kilogram of animal. This biomass estimate is also known as the population correction unit or PCU[8].

CIPARS collects data from sampled farms for 1 production period, not for a full calendar year. This type of sample data needs a denominator that accounts for the duration of time that the animals were studied in addition to the number of animals. For this reason, we use a "per animal-day" or "per 1,000 animal-days" denominator to report AMU from a sample of farms and production periods.

Table 1. 1 provides further details about 3 of the more common metrics that CIPARS reports and the purpose and suitability of each metric. More detail about how AMU data are measured and reported is provided in the AMU Chapter.

[8] European Surveillance of Veterinary Antimicrobial Consumption (ESVAC). Available at: http://www.ema.europa.eu/ema/index.jsp?curl=pages/regulation/document_listing/document_listing_000302.jsp. Accessed June 2018.

Table 1. 1 Commonly used metrics for reporting antimicrobials intended for use in animals and why these metrics are used

	mg/PCU (PCU = Population correction unit)	nDDDvetCA/1,000 animal-days at risk (nDDDvetCA = the number of Defined Daily Doses, based on Canadian standard daily doses)	nDDDvetCA/PCU
Why use this metric?	◦ Provides an estimate of the selection pressure of total antimicrobial use in the context of the animal biomass potentially exposed to the antimicrobials. ◦ The kg is a technical unit of measurement, which provides a raw measure of exposure.	◦ This metric adjusts the raw quantity of antimicrobials used by how much of the antimicrobial needs to be given on a daily basis (i.e., how strong the drug is). ◦ This metric adjusts for how many animals were under evaluation, how heavy on average they could be, and for how long. This adjustment is necessary because the farm data are based on sampled flocks or herds for one production cycle (i.e., we do not have census level data and we do not study the farms for a calendar year).	◦ This metric adjusts the raw quantity of antimicrobials used by how much of the antimicrobial needs to be given on a daily basis (i.e., how strong the drug is). ◦ This metric adjusts for how many animals were under evaluation and how heavy on average they could be at the likely time of treatment.
Metric description	◦ Milligrams of antimicrobial reported, adjusted for the size of the animal population and average weight at treatment of the live animals. ◦ 1 PCU = 1 kg of animal.	◦ Numerator: nDDDvetCA = mg of antimicrobial reported divided by the average daily dose (DDDvetCA; mg/kg animal). ◦ Denominator: adjusts for the total number of animals under surveillance, the standard animal weight (kg animal) and the time under observation measured in days (grow-out cycle or observation period per flock or herd); denominator units=1,000 animal-days. ◦ Ratio: numerator/denominator; units = number of DDDvetCA per 1,000 animal-days.	◦ Numerator: nDDDvetCA = mg of antimicrobial reported divided by the average daily dose (DDDvetCA). ◦ Denominator: adjusted for the size of the animal population and average weight at treatment of the live animals; denominator units = $kg_{animal.}$ ◦ 1 PCU = 1kg of animal. ◦ Ratio: numerator/denominator; units = number of DDDvetCA per PCU.

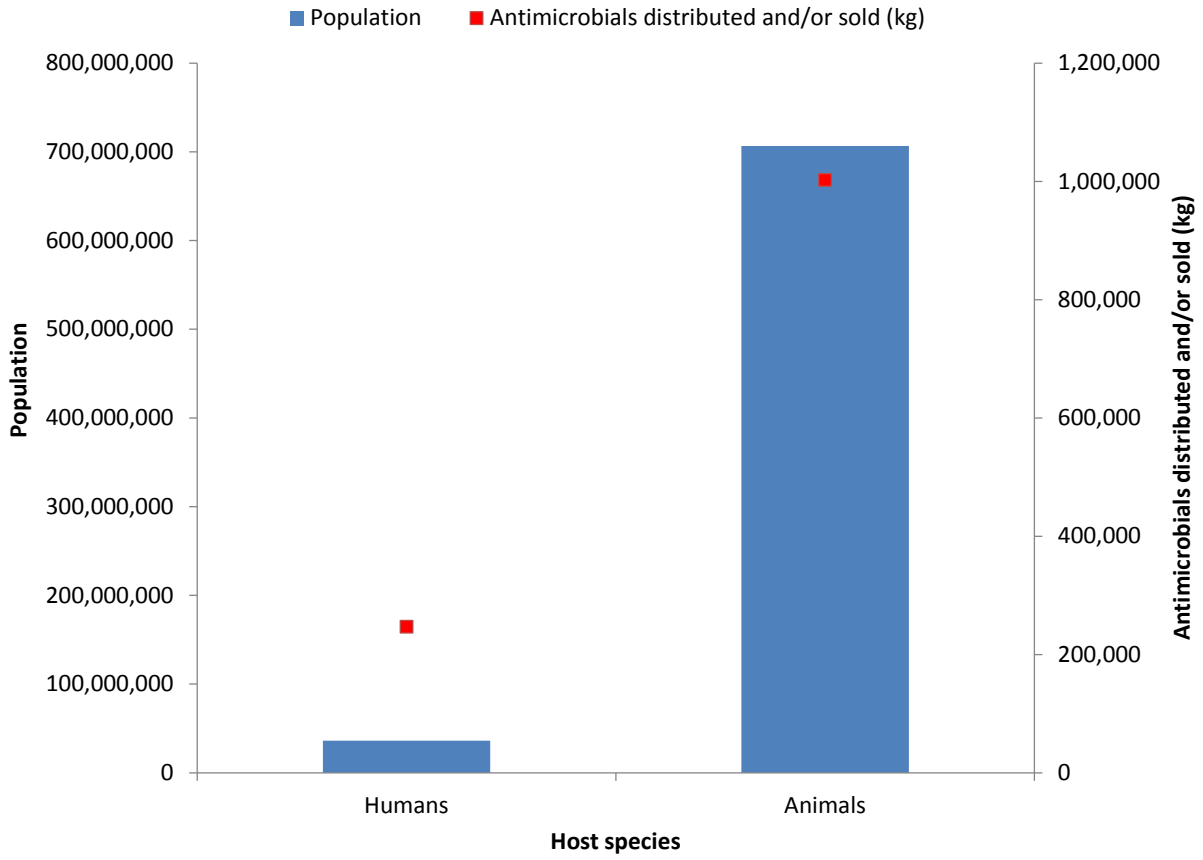
Table 1. 1 Commonly used metrics for reporting antimicrobials intended for use in animals and why these metrics are used (continued)

	mg/PCU (PCU = Population correction unit)	nDDDvetCA/1,000 animal-days at risk (nDDDvetCA = the number of Defined Daily Doses, based on Canadian standard daily doses)	nDDDvetCA/PCU
Where do we apply this metric?	◦ This metric is applied to the national distribution data. ◦ This metric is applied to our farm data to provide a rough comparison to the national distribution data.	◦ This metric is applied to the farm data (as animal species level information is required in assigning nDDDvetCA standards).	◦ This metric is applied to the farm data (as animal species level information is required in assigning DDDvetCA standards).
Limitations	◦ Every kg of antimicrobial is treated equally; the metric cannot account for differences in daily doses of the antimicrobials required to achieve an effect. ◦ The PCU assumes that the standard average weight of animal at the likely time of treatment is constant and approximates field conditions. ◦ The PCU treats one kilogram of a chicken to be equivalent to one kilogram of a pig etc.	◦ The nDDDvetCA may not reflect actual used doses, as the nDDDvetCA are an average of all unique doses labelled for prevention and treatment use in Canada. ◦ True use may be different than labelled use doses. ◦ The metric does not account for how long each treatment is administered. ◦ The metric assumes a constant rate of antimicrobial use for the defined time period.	◦ The nDDDvetCA may not reflect actual used doses, as the nDDDvetCA are an average of all unique doses labelled for prevention and treatment use in Canada. ◦ True use may be different than labelled use doses. ◦ The metric does not account for how long each treatment is administered. ◦ The PCU assumes that the standard average weight of animal at the likely time of treatment is constant and approximates field conditions. ◦ The PCU treats 1 kg of a chicken to be equivalent of 1 kg of a pig etc.
What types of evaluations do we use this metric for?	◦ Total antimicrobial use or antimicrobial consumption (overall selection pressure) ◦ Trends over time by antimicrobial class ◦ Comparison between regions (international and within Canada) ◦ Comparison between species and reasons for AMU	◦ Total antimicrobial use ◦ Trends over time by antimicrobial class ◦ Comparison between regions (within Canada) ◦ Comparison between species	◦ Total antimicrobial use ◦ Trends over time by antimicrobial class ◦ Comparison between regions (within Canada) ◦ Comparison between species
Harmonization	◦ This metric is currently being used by 30 countries in Europe via the European Surveillance for Veterinary Antimicrobial Consumption Project and also by Japan.	◦ The numerator is developed per guidance recommended by the European Surveillance for Veterinary Antimicrobial Consumption. ◦ The denominator is a commonly used denominator for epidemiological reporting of rates generated from a sampled population.	◦ The numerator is developed per guidance recommended by the European Surveillance for Veterinary Antimicrobial Consumption. ◦ The denominator is novel in this application, though under discussion in several international fora.

Comparing humans, animals, and crops

Canada is a major producer of food animals for domestic and international markets. In 2016, there were approximately 19 times more animals in Canada than people; which is an underestimate of the number of animals because the statistics on fish are reported as kg of fish, not number of live animals, and hence cannot be included. Four times more kg of antimicrobials were sold for use in animals than people in 2016 (Figure 1. 2). After adjusting for underlying biomass (i.e., mg drug/PCU or mg drug/kg human), this translates into 1.5 times more antimicrobials distributed for use in animals than humans. This is using European average weights at treatment for animals. If Canadian average weights at treatment are used instead, this ratio drops to 1.3. Note that for the data about antimicrobials intended for use in animals, antimicrobials imported as active pharmaceutical ingredients intended for further compounding or imported for own use purposes are not included.

Figure 1. 2 Human and animal population estimates with total kilograms of antimicrobials distributed and/or sold, 2016

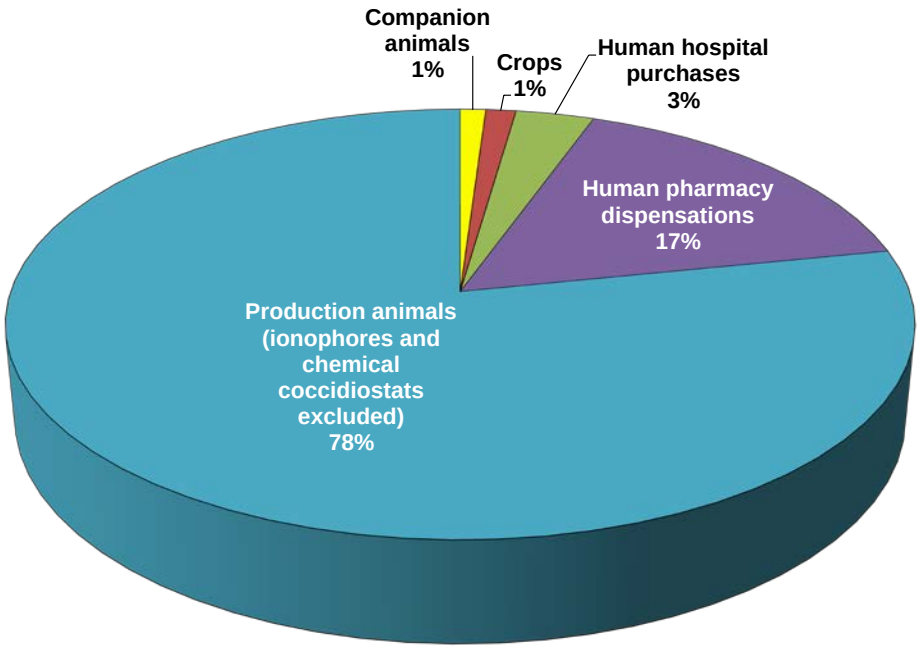


Data sources: Human pharmacy and hospital data from IQVIA via the Canadian Antimicrobial Resistance Surveillance System, Canadian Animal Health Institute, Statistics Canada, Agriculture and Agri-food Canada, and Equine Canada.

Animal distribution data do not include antimicrobials imported under the “own use” provision or imported as active pharmaceutical ingredients intended for further compounding; hence, are underestimates of total quantities used.

When measured by kilograms of active ingredient, approximately 78% of antimicrobials distributed or sold in 2016 were intended for production animals, 20% were for humans, 1% for crops and 1% for companion animals (Figure 1. 3).

Figure 1. 3 Proportion of total kilograms of antimicrobials distributed and/or sold in Canada, by sector



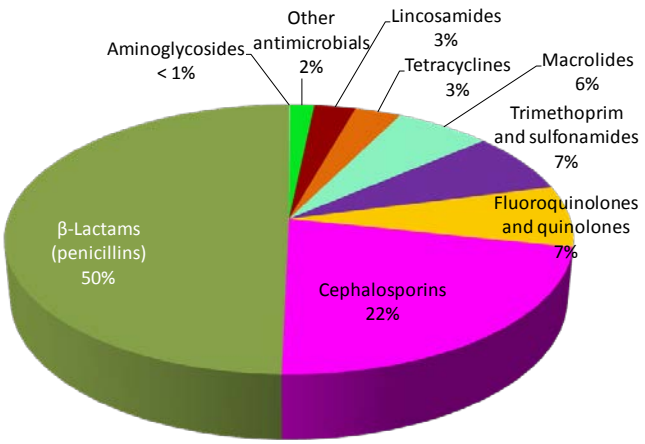
Data sources: Human pharmacy and hospital data from IQVIA via the Canadian Antimicrobial Resistance Surveillance System, Canadian Animal Health Institute, Health Canada's Pest Management Regulatory Agency.

Animal distribution data do not include antimicrobials imported under the "own use" provision or imported as active pharmaceutical ingredients intended for further compounding; hence, are underestimates of total quantities used.

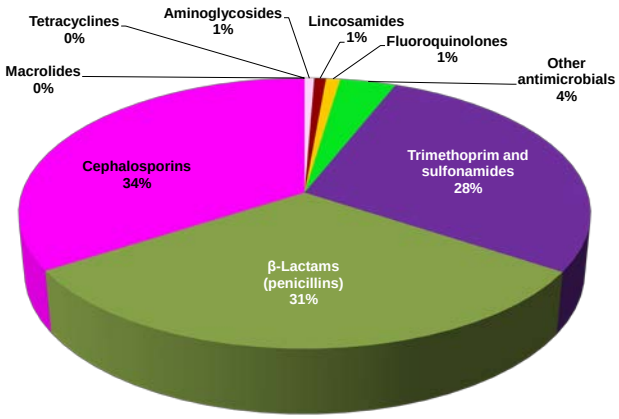
Similar antimicrobials are used in humans and animals; however, some antimicrobial classes are sold or distributed more for use in humans than animals and vice-versa. In humans, the predominant classes of antimicrobials sold (by kg active ingredient in descending order) were β-lactams, cephalosporins, and fluoroquinolones. In companion animals, the predominant classes of antimicrobials were cephalosporins, β-lactams and trimethoprim and sulfonamides; whereas in production animals, the predominant classes of antimicrobials distributed for sale were tetracyclines, β-lactams, and "other antimicrobials" (Figure 1. 4). Across all sectors, the β-lactams were one of the top antimicrobial classes distributed/sold on a per kg of antimicrobial basis.

Figure 1. 4 The relative proportions of antimicrobial classes differ between animals and people (kg active ingredient)

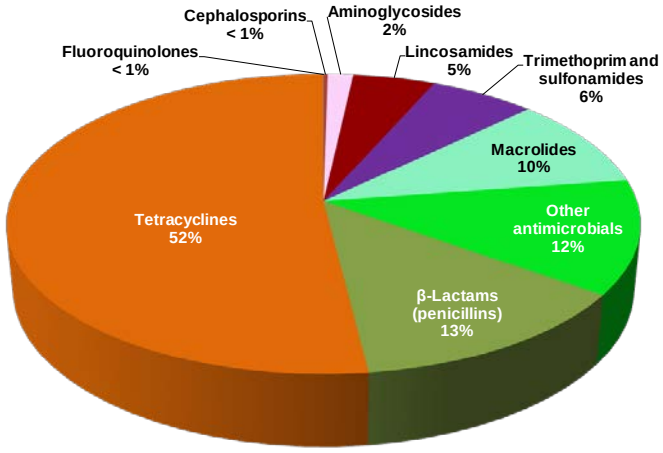
a) Humans



b) Companion animals



c) Production animals



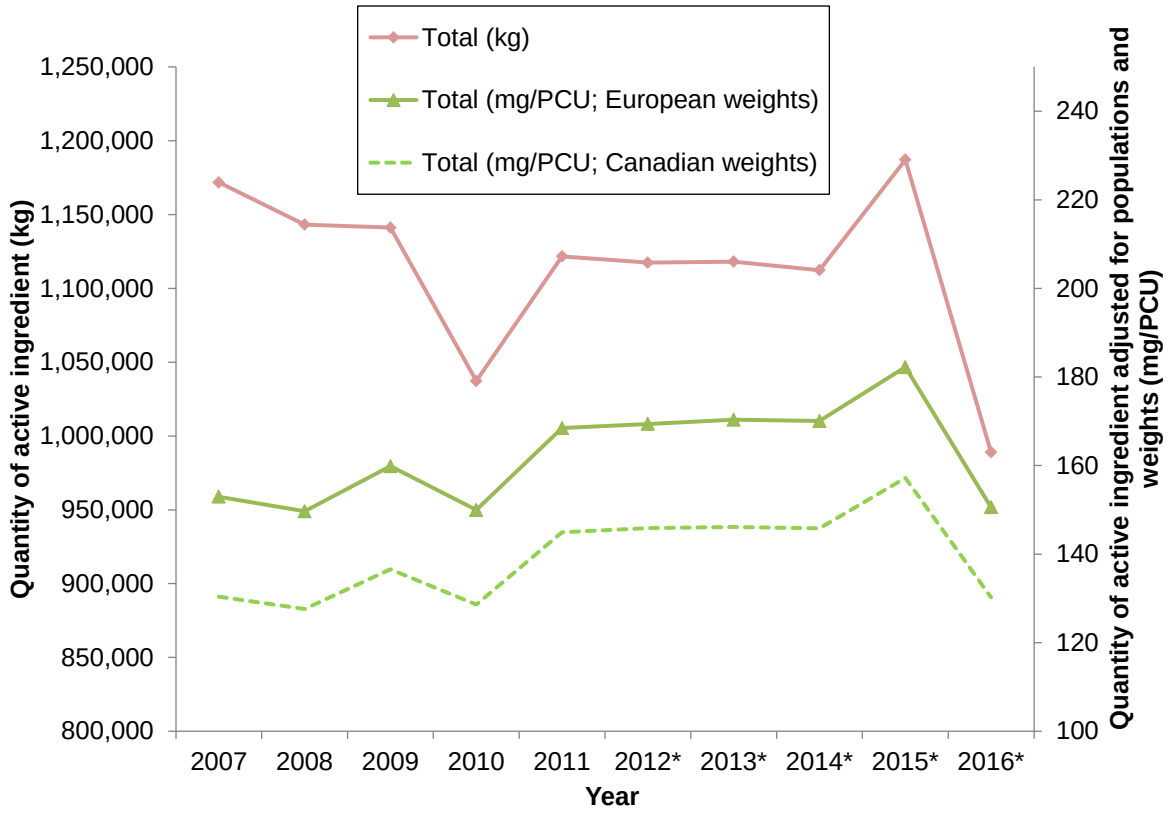
Data sources: Human pharmacy and hospital data from IQVIA via the Canadian Antimicrobial Resistance Surveillance System, Canadian Animal Health Institute, Statistics Canada, Agriculture and Agri-food Canada, and Equine Canada.

Animal distribution data do not include antimicrobials imported under the “own use” provision or imported as active pharmaceutical ingredients intended for further compounding; hence, are underestimates of total quantities used.

Other antimicrobials for the animal data for 2016 included: avilamycin, bacitracins, bambermycin, chloramphenicol, chlorhexidine gluconate, florfenicol, fusidic acid, nitarsone, nitrofurantoin, nitrofurazone, novobiocin, polymixin, tiamulin, and virginiamycin. Other antimicrobials for the human data included: bacitracin, chloramphenicol, colistin, colistimethate, daptomycin, fixadomycin, fosfomycin, fusidic acid, linezolid, methenamine, metronidazole, nitrofurantoin, polymyxin B, quinupristin-dalfopristin, and vancomycin.

In 2016, the total quantities of antimicrobials distributed for sale for use in animals declined (Figure 1. 5). The total kg used has dropped 14% since 2007 and is 17% lower than 2015 levels. In terms of use per kg animal, use declined 2% compared with 2007 levels using European standard weights of animals (0% change if using the Canadian standards) and was 18% lower in 2016 compared to 2015 using European standard weights of animals (17% using Canadian standards).

Figure 1. 5 Antimicrobials distributed for sale for use in animals over time (kg of active ingredient and mg/PCU), 2007 to 2016



Data sources: Canadian Animal Health Institute, Statistics Canada, Agriculture and Agri-food Canada, Equine Canada, and European Medicines Agency.

PCU = population correction unit.

The data used for live horses was from 2010; more recent data were unavailable at the time of writing.

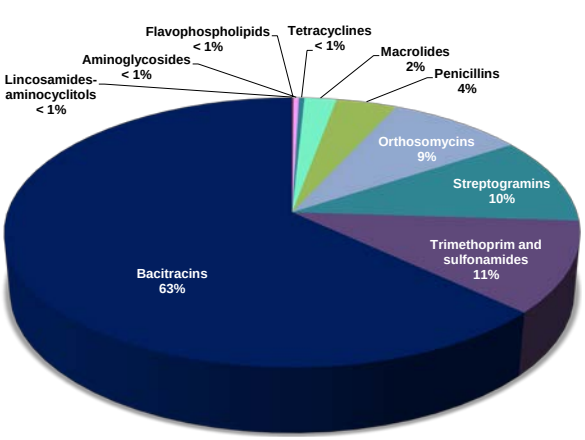
Animal distribution data do not include antimicrobials imported under the "own use" provision or imported as active pharmaceutical ingredients intended for further compounding; hence, are underestimates of total quantities used.
* Indicates years where data exclude antimicrobials sold for use in companion animals.

Comparing farm antimicrobial use data over time and between animal sectors

There are important differences in the types and relative quantities of antimicrobials reported for use between food animal species included in the CIPARS Farm Surveillance component (Figure 1. 6). For broiler chickens (feed, water and injection data), the predominant antimicrobial classes used in 2016 were bacitracins, trimethoprim and sulfonamides and streptogramins. Similarly in turkeys, the most commonly used antimicrobial classes in 2016 were bacitracins, streptogramins and tetracyclines. Conversely, in grower-finisher pigs (feed only data), the predominant antimicrobial classes used were tetracyclines, lincosamides and macrolides (Figure 1. 6). The β-lactams were not one of the predominant classes reported being in any of these animal species.

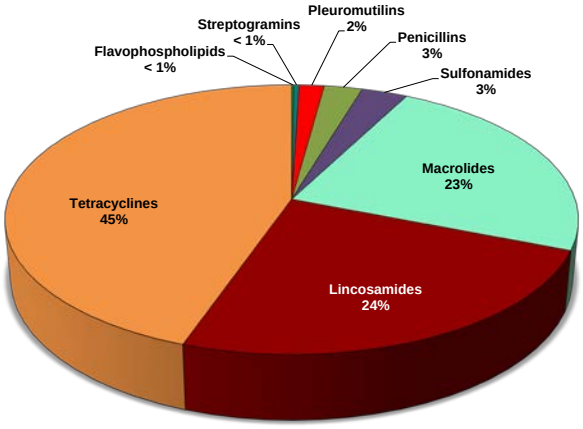
Figure 1. 6 The relative proportions of antimicrobial classes reported in grower-finisher pigs, broiler chickens and turkeys (mg/PCU), CIPARS 2016

a) Broiler chickens



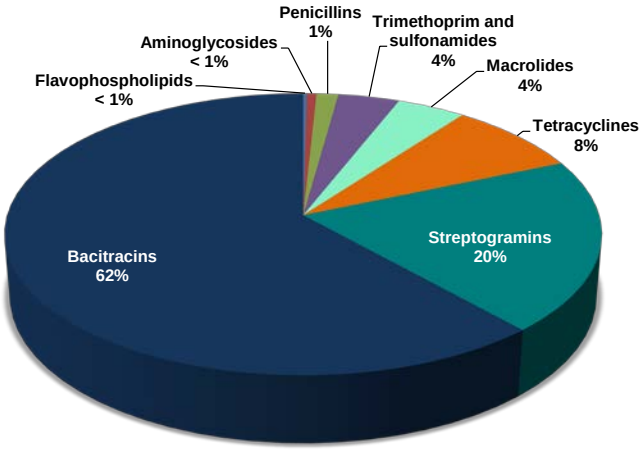
Antimicrobial use in feed, water, and injection.

b) Grower-finisher pigs



Antimicrobial use in feed only.

c) Turkeys

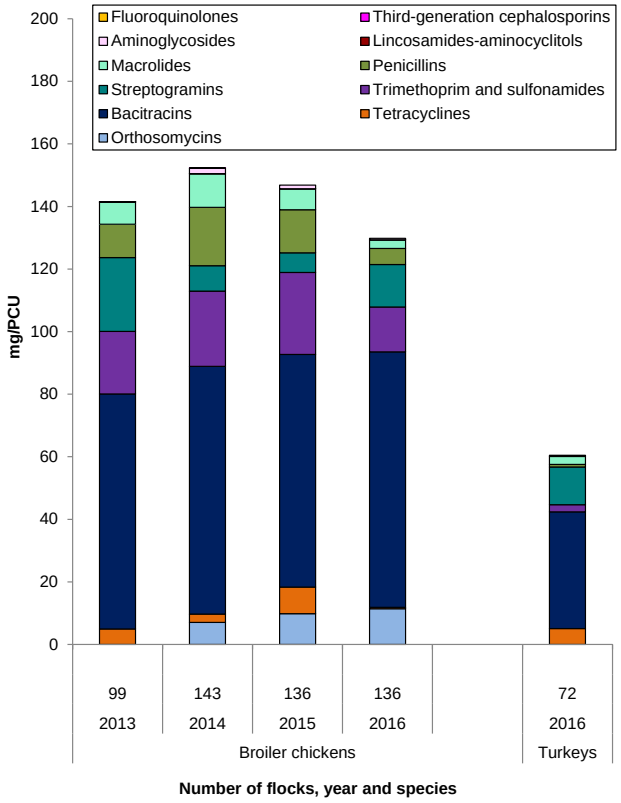


Antimicrobial use in feed, water, and injection.

Similar to the national distribution data, which showed a drop in total quantity of antimicrobials distributed for use in animals, the CIPARS Farm Surveillance component also showed a drop in mg/PCU in 2016 compared with 2015 data. This decline was identified in both broiler chickens and grower-finisher pigs (Figure 1. 7). Turkey AMU data were presented for the first time in 2016; hence no temporal analysis was possible however, the overall reported use in turkeys was much lower that for broiler chickens and grower-finisher pigs in 2016.

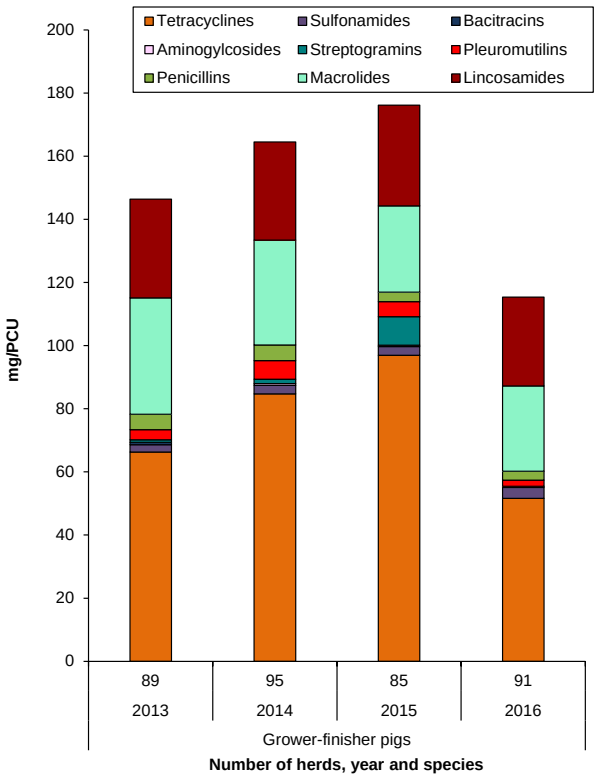
Figure 1. 7 Temporal trends of mg/PCU in broiler chickens, turkeys, and grower-finisher pigs

a) Broiler chickens and turkeys



Antimicrobial use in feed, water, and injection.

b) Grower-finisher pigs



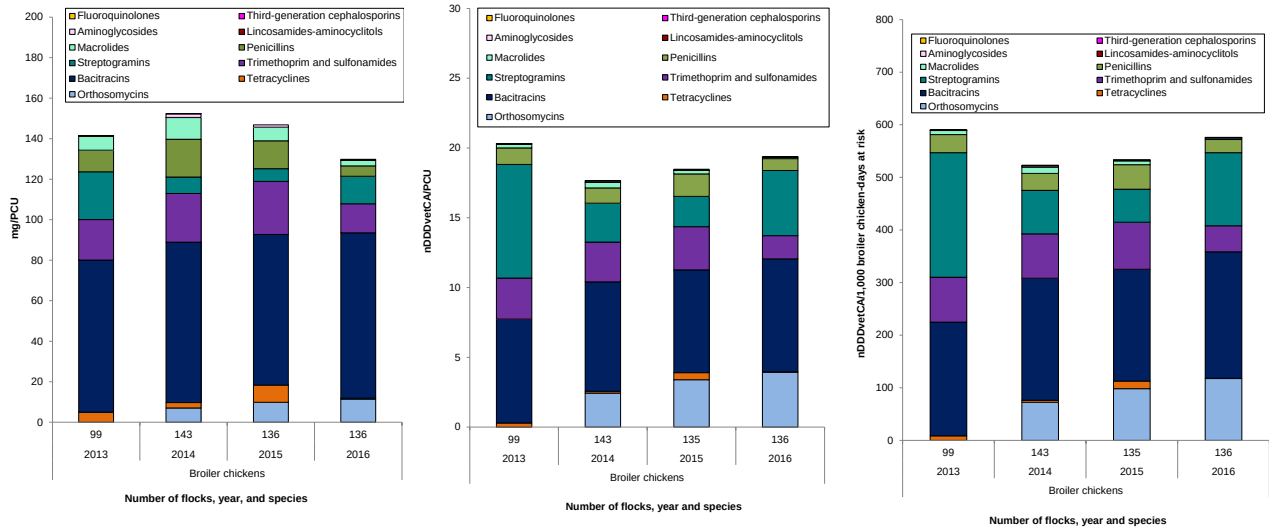
Antimicrobial use in feed only.

However, when we dig a little deeper and adjust the estimates by the average daily dose (DDDvetCA), the trends change (Figure 1. 8). Whereas the mg/PCU decreased in 2016 for broiler chickens compared to 2015 data, the nDDDvetCA/PCU in 2016 was higher than it was in 2015. In other words, the number of doses per kg of animal actually increased in 2016 for broiler chicken. This can be explained by the change in quantity of use to more antimicrobials that have lower feed inclusion rates and lower DDDvetCA standards such as avilamycin (an orthosomycin) and virginiamycin (a streptogramin). Inclusion rates and DDDvetCA standards can be found in the AMU and Methods sections of this report.

Using mg/PCU, the most common antimicrobials used in broiler chickens were bacitracins, trimethoprim and sulfonamides, and streptogramins. In Figure 1. 8, the 2 sub-figures on the right (nDDDvetCA/PCU and nDDDvetCA/1,000 broiler chicken-days at risk) show similar trends in use. This is expected because the numerator for both is the same and while different denominators are used, they rely on very similar information. But these 2 sub-figures show that between 2015 and 2016 more doses per kg of animal (or per 1,000 animal-days at risk) were used. Altogether, the data presented in Figure 1. 8 suggest that while fewer mg of antimicrobials per kg of animals were used, this was achieved by giving more doses per kg of animal (or per 1,000 animal-days at risk). Similarly, the top antimicrobials were slightly different when the dose metrics were used: bacitracins were still the most commonly reported antimicrobials but streptogramins were the second most common and orthosomycins the third.

Figure 1. 8 Temporal trends in mg/PCU, nDDDvetCA/PCU and nDDDvetCA/1,000 broiler chicken-days at risk in broiler chickens, CIPARS 2013 to 2016

a) mg/PCU **b) nDDDvetCA/PCU** **c) nDDDvetCA/1,000 broiler chicken-days at risk**

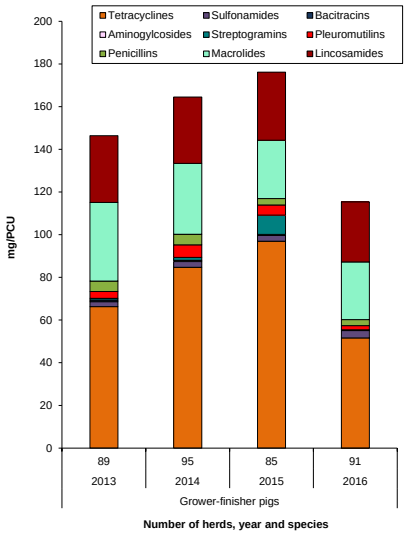


Antimicrobial use in feed, water, and by injection.

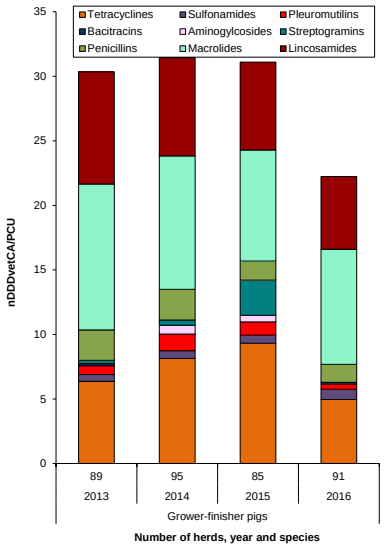
In grower-finisher pigs, the number of doses per kg of animal decreased in 2016; results using this metric showed the same trend as the results using the mg/PCU indicator (Figure 1. 9). In other words, the total mg of drug per kg of animal declined because of a decrease in the number of doses administered per animal-day at risk. The top 3 drugs were the same regardless of metric used, but their relative importance changed. On a mg/PCU basis, the top reported drugs in order were tetracycline, tylosin and lincomycin; whereas when we accounted for the number of doses, the order became tylosin, lincomycin and tetracycline.

Figure 1. 9 Temporal trends of mg/PCU, nDDDvetCA/PCU and nDDDvetCA/1,000 grower-finisher pig-days at risk in grower-finisher pigs, CIPARS 2013 to 2016

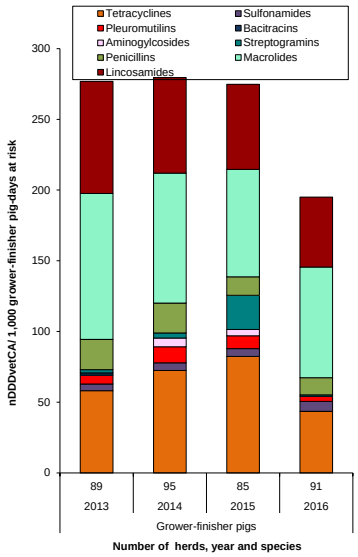
a) mg/PCU



b) nDDDvetCA/PCU



c) nDDDvetCA/1,000 grower-finisher pig-days at risk



Antimicrobial use in feed only.

Frequency of use

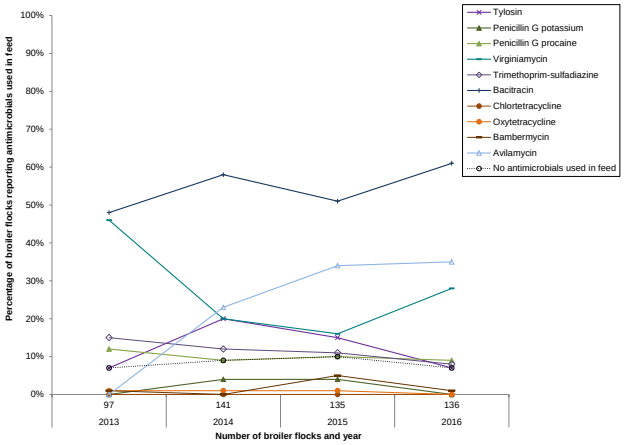
The AMU unit of measurement that we integrate most often with the CIPARS AMR data is frequency of farms reporting the use of the antimicrobial. In Figure 1. 10, the percentage of all farms under surveillance for each calendar year that reported using specific antimicrobials in feed is presented. The frequency of AMU in feed changes over time and by drug class. Key trends that emerge from Figure 1. 10 include a significant decrease in the proportion of swine farms reporting tylosin use since 2009. For broilers, there was a significant increase in avilamycin use between 2013 and 2016.

In terms of antimicrobials administered in the water, the frequency of this use practice has not changed in these 2 animal species over time and remains uncommon. Frequency of antimicrobial use via water in turkeys was similar to broiler chickens, in which only 11% of the farms reported administering antimicrobials via the water. More data on frequency of use can be found in the AMU chapter of this report.

Similar to reported frequency of use in feed, use by injection has also changed over time (Figure 1. 11). The key finding for grower-finisher pigs was that, although there has been a recent decrease, overall there has been a significant increase in the number of farms reporting florfenicol use between 2009 and 2016. For broiler chickens, all the data presented in Figure 1. 11 is from the hatchery level; there is no reported AMU by injection in broilers. Since 2015, there has been no reported use of ceftiofur. Over the same time period, the proportion of flocks that reported not using any antimicrobials by injection at the hatchery increased.

Figure 1. 10 Temporal trends in frequency of farms reporting antimicrobial use in feed in broiler chickens and grower-finisher pigs, CIPARS 2009 to 2016

a) Broiler chickens



b) Grower-finisher pigs

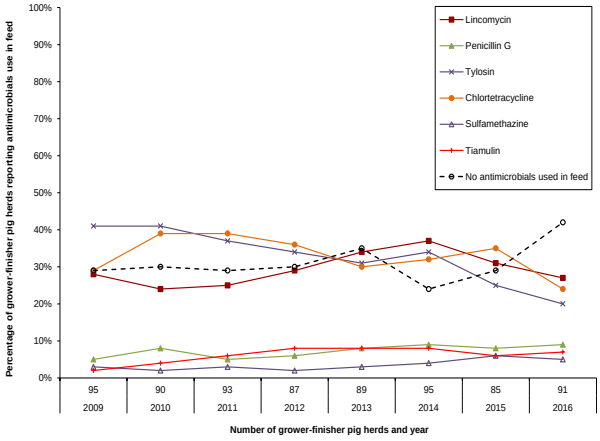
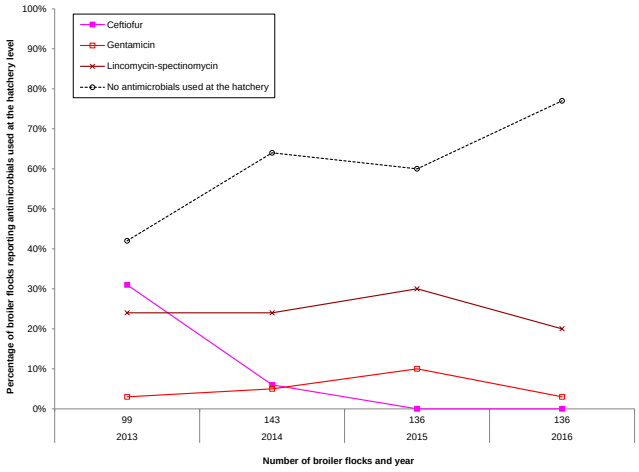
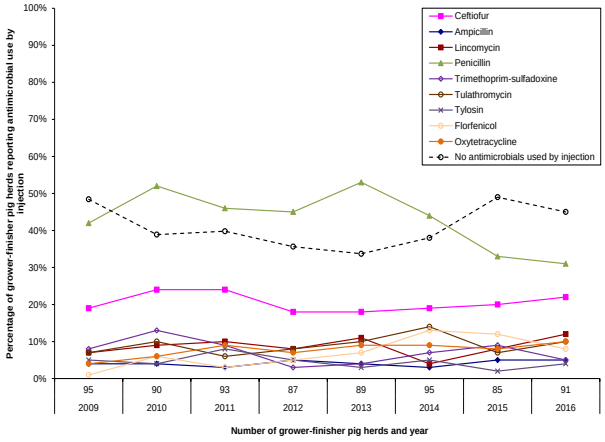


Figure 1. 11 Temporal trends in frequency of farms administering antimicrobials by injection in broiler chickens and grower-finisher pigs, CIPARS 2009 to 2016

a) Broiler chickens



b) Grower-finisher pigs

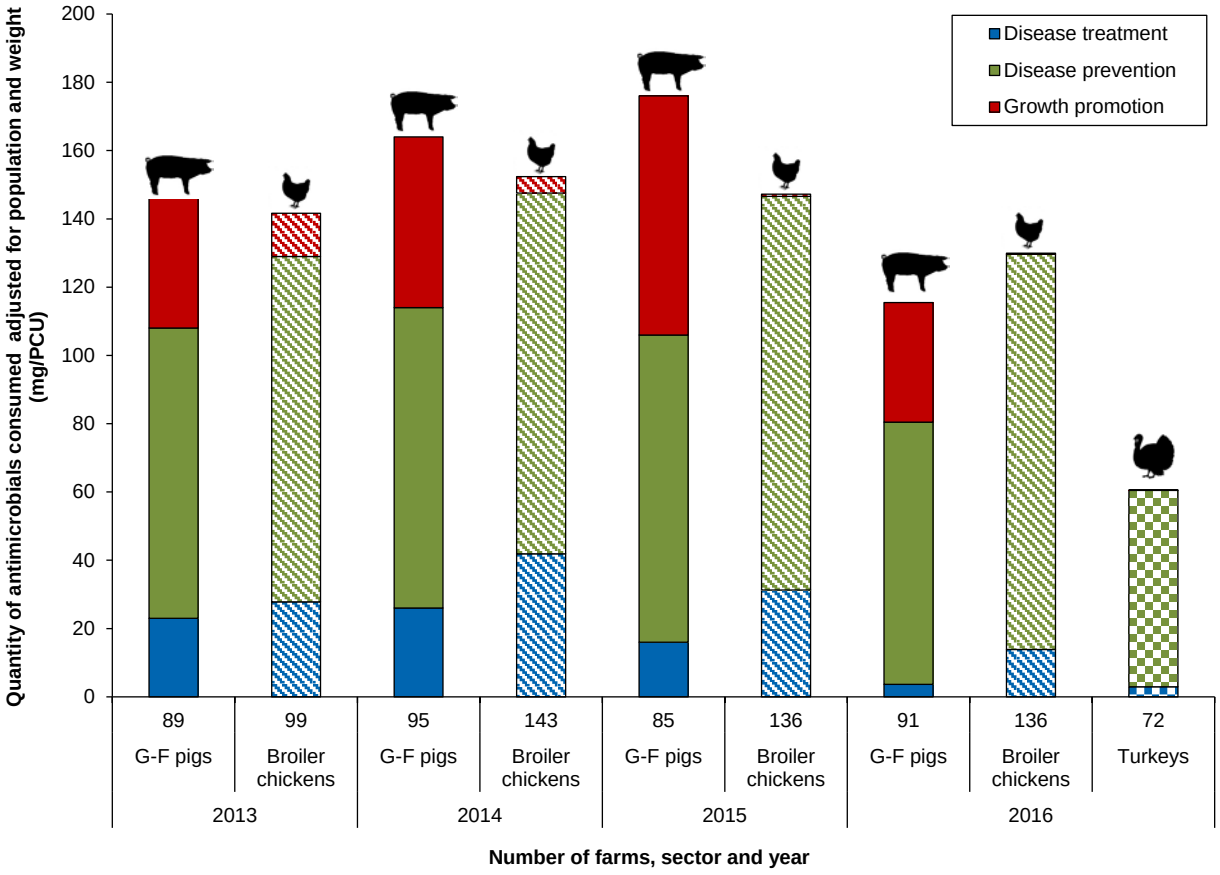


Reasons for use

Through the CIPARS Farm Component, we collected data on the primary reasons for use: growth promotion, disease prevention or therapy (disease treatment). For disease prevention and therapy, we collected more information about specific conditions; these data are shown in the AMU chapter. In broiler chickens, turkeys and grower-finisher pigs, the predominant reason for administering antimicrobials in 2016 was for disease prevention (Figure 1. 12).

In 2016, reported antimicrobial use (mg/PCU) declined in broiler chicken and grower-finisher swine, especially for growth promotion purposes (Figure 1. 12).

Figure 1. 12 Quantity of antimicrobials used (mg/PCU) by reason for use, CIPARS 2013 to 2016



G-F = grower-finisher.

Swine data are for antimicrobial use in feed only; chicken and turkey data include all routes of administration.

Integrated antimicrobial resistance data

Increasing numbers of highly drug resistant isolates

Multidrug resistance (MDR) occurs when bacteria are resistant to multiple antimicrobial agents. These types of bacteria pose the greatest threat to public health because when these bacteria cause illness, there are few or no treatment options left.

Depending on the year, CIPARS tests for resistance in *Salmonella* and generic *E. coli* to 6 or 7 different antimicrobial classes. The number of drug classes tested depends on the configuration of the test panel used in a particular surveillance year. In 2016, CIPARS tested for resistance to 7 antimicrobial classes; meropenem (a carbapenem antimicrobial) was added to the panel in 2016, but as this antimicrobial is a β-lactam which are already represented by other antimicrobials on the test panel, the number of classes tested remained the same as in 2015.

Bacteria that are resistant to the greatest number of antimicrobial classes are more often recovered from sick people and animals that may have already been treated with antimicrobials. There are no international standards defining highly resistant isolates although many different approaches have been described and proposed, such as multiclass resistance (CIPARS), multidrug resistant, extensively drug resistant and pan-drug resistant[9]. CIPARS is paying particular attention to those bacteria resistant to more than 5 antimicrobial classes which we then identify as “highly drug resistant”.

In 2016, 106 *Salmonella* isolates from CIPARS were identified as highly resistant: 52 clinical cattle isolates, 21 swine isolates (4 from healthy pigs and 17 sick pigs), 32 clinical human isolates and 1 isolate from a sick dog (Table 1. 2). In Figure 1. 13, the frequency of highly resistant *Salmonella* isolates from agri-food and human sources appears to be increasing yet again in 2016. Most of the highly resistant agri-food isolates identified to date were recovered from clinically sick cattle and most of these have been *S*. Dublin and *S*. Typhimurium. Clinical isolates are the only source of *Salmonella* from cattle in CIPARS surveillance due to the low prevalence of *Salmonella* in abattoir feedlot cattle and retail beef. Also worthy of note in 2016, is the increasing trend seen in pigs; most of the highly resistant isolates were recovered from clinically sick pigs but there have also been a few (n = 3) from the abattoir component and one from the farm component. No highly resistant strains of *Salmonella* have been detected from chicken sources and very few from turkey.

It is important to note that CIPARS does not receive all clinical *Salmonella* isolates from all provincial animal health laboratories and therefore coverage may vary considerably among provinces. As well, some submissions are likely clustered around disease outbreak events, diagnostic investigations or monitoring programs and thus may represent repeat submissions from the same animal or farm.

The number of highly resistant *Salmonella* isolates from humans has also been increasing. Four human isolates have shown resistance to all 7 antimicrobial classes tested: 2 isolates of *S*. 4,[5],12:i:- (2012, 2016), 1 isolate of *S*. Newport (2014), and 1 isolate of *S*. Kentucky (2015).

[9] German GJ, Jamieson FB et al. Interim Recommendations for the Reporting of Extensively Drug Resistant and Pan Drug Resistant Isolates of Enterobacteriaceae, *Pseudomonas aeruginosa*, *Acinetobacter* spp. and *Stenotrophomonas maltophilia*. Can Comm Dis Rep 2016;42:91-7.

In 2016, just 9 generic *E. coli* isolates were identified as highly resistant: 4 from chicken (2 on farm, 1 at abattoir and 1 at retail), 4 from pigs (2 on farm and 2 at retail) and 1 from retail turkey meat (Figure 1. 14). Overall, fewer *E. coli* isolates have demonstrated resistance to more than 5 antimicrobial classes, but highly resistant isolates emerged earlier in *E. coli* than *Salmonella*. Since 2004, 77 *E. coli* isolates have demonstrated resistance to more than 5 antimicrobial classes and 52 (68%) of these isolates were detected in the past 5 years. Four *E. coli* isolates have been resistant to all antimicrobial classes tested (n = 7): 2 in 2011 (1 from pigs on farm and the other from retail pork meat), 1 in 2013 from retail ground beef, and 1 in 2014 from turkey on farm.

The paucity of highly resistant *E.coli* isolates among the CIPARS isolates may be due, in part, to a lack of clinical isolates. CIPARS does not include clinical *E. coli* from animals or humans as part of core surveillance; all of the *E. coli* isolates are recovered from apparently healthy animals or food products. One important difference in the *E. coli* data compared with the *Salmonella* data is that highly resistant isolates were detected from chickens and chicken meat.

Table 1. 2 *Salmonella* serovars resistant to more than 5 antimicrobial classes by species and surveillance component, CIPARS 2016

CIPARS component	Species					
	Humans	Cattle	Pigs	Chickens	Turkeys	Dogs
Diagnostic/clinical	Typhimurium (13) Infantis (7) Dublin (6) 4,[5], 12:i:- (5) Newport (1)	Dublin (43) 4,[5],12:i:- (5) Typhimurium (3) 9,12:-:- (1)	4,[5],12:i:- (6) Typhimurium (6) Ohio var. 14+ (4) Infantis (1)	0	0	Rough:-:- (1)
Abattoir	0	0	Ohio (2) Ohio var. 14+ (1)	0	0	0
Farm	0	0	Ohio (1)	0	0	0
Total number of isolates	**32**	**52**	**21**	**0**	**0**	**0**

Figure 1. 13 The number of highly resistant (resistant to greater than 5 antimicrobial classes) *Salmonella* isolates by year from human and agri-food sources, CIPARS 2007 to 2016

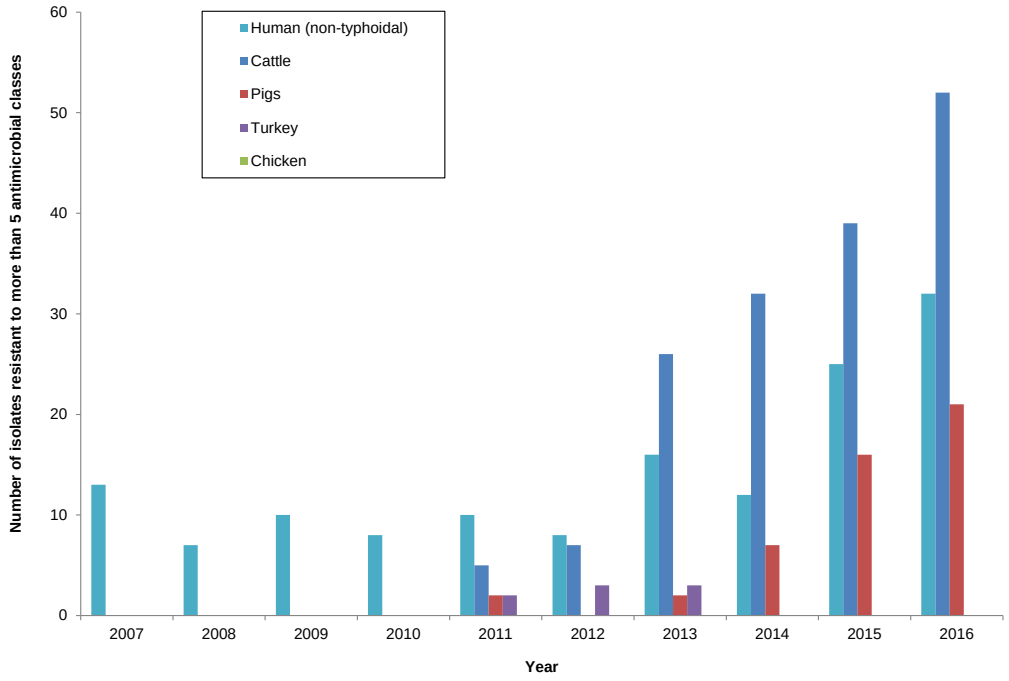
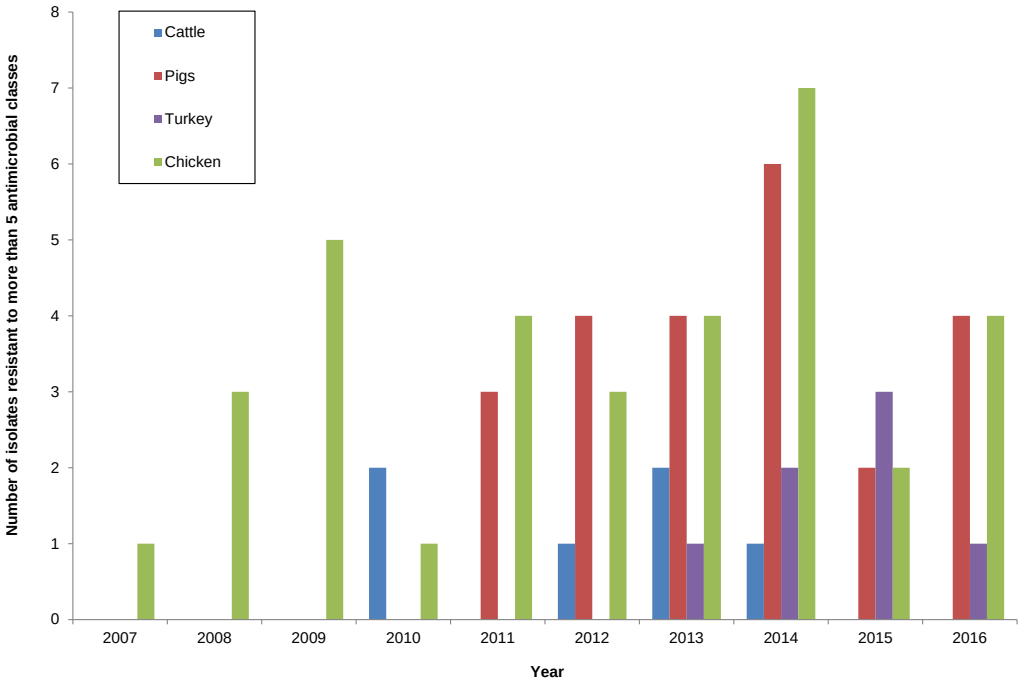


Figure 1. 14 The number of highly resistant (resistant to greater than 5 antimicrobial classes) *Escherichia coli* isolates by year from human and agri-food sources, CIPARS 2007 to 2016



Fluoroquinolone resistance in *Campylobacter*

Fluoroquinolone resistance in *Campylobacter* is one of the main issues of concern to CIPARS. Ciprofloxacin (a fluoroquinolone) is an antimicrobial of very high importance to human medicine (Category I) that is frequently used in people to treat a variety of infections.

For the first time in 2016, we were able to report limited human data for 3 regions: British Columbia (data from the Antimicrobial Resistance Trends in the Province of British Columbia: 2014 Report[10]), Ontario and the Prairies (data from FoodNet Canada) (Figure 1. 15). Resistance to ciprofloxacin was more commonly identified in human isolates from British Columbia and Alberta than from Ontario. In collaboration with FoodNet Canada, CIPARS will be able to access and test more human *Campylobacter* isolates in the coming years to help determine if this trend continues and begin to investigate to what extent fluoroquinolone-resistant *Campylobacter* from animals and food contribute to resistant infections in people.

Resistance to ciprofloxacin in *Campylobacter* from chicken continued to vary over time and across regions although the highest proportion of resistant isolates continued to be from British Columbia (Figure 1. 15). In 2016, resistance to ciprofloxacin in *Campylobacter* from chicken was highest in British Columbia for all surveillance components (farm, abattoir and retail) but resistance at abattoir and retail did decrease from 2015 levels. Similarly, resistance among *Campylobacter* isolates from turkeys on farm was 23% (40/171) and most of these (n = 37) were from British Columbia.

Despite the different and changing trends in resistance to ciprofloxacin among *Campylobacter* isolates from different CIPARS surveillance components and regions, there has been no reported fluoroquinolone use on sentinel broiler chicken farms since 2013. In addition for 2016, there was also no reported fluoroquinolone use on participating turkey farms. In the United States, fluoroquinolone-resistant *Campylobacter* persisted on broiler farms that had not used this category of antimicrobial for several years[11,12]. Fluoroquinolone-resistant *Campylobacter* may have a competitive advantage over susceptible strains even in the absence of selection pressure[13]. CIPARS continues to work with producers and veterinarians to explore other potential antimicrobial uses and management factors that might explain the variable levels of resistance to ciprofloxacin observed across the regions.

Ciprofloxacin resistance in *Campylobacter* from non-chicken sources is also slowly increasing. In abattoir cattle, ciprofloxacin resistance increased to 14% in 2016 compared to 11% in 2015 and just 5% in 2014. Among abattoir isolates from pigs, resistance increased in 2016 (to 13%) and resistance was highest in Québec. It is important to note that most of the isolates from pigs are *C. coli*. *Campylobacter jejuni* is most commonly associated with human infections.

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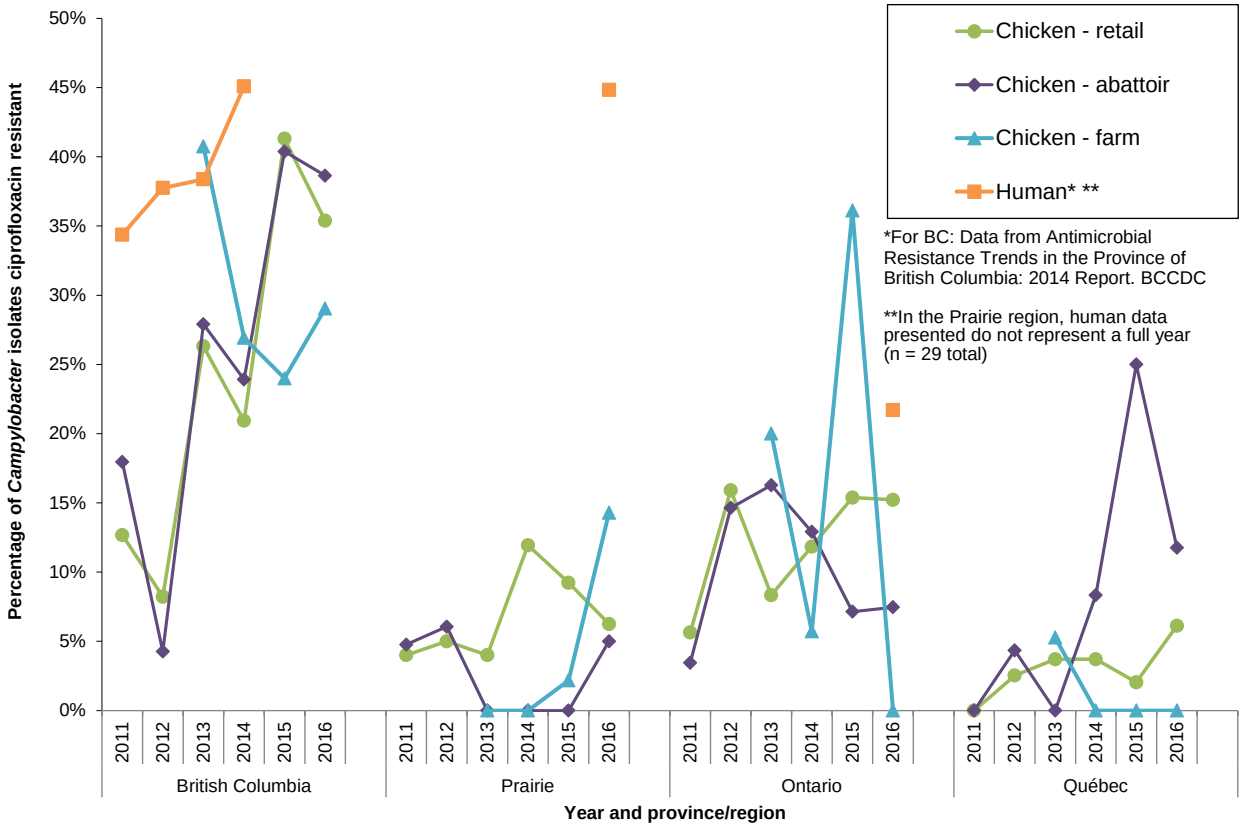
[10] Antimicrobial Resistance Trends in the Province of British Columbia: 2014 Report. BCCDC.

[11] Price LB, Johnson E, Vailes R and Silbergeld E. Fluoroquinolone-Resistant *Campylobacter* Isolates from Conventional and Antibiotic-Free Chicken Products. 2005.Environ Health Perspect 113:557–560.

[12] Price LB, Lackey LG, Vailes R and Silbergeld E. The Persistence of Fluoroquinolone-Resistant *Campylobacter* in Poultry Production. Environ Health Perspect. 2007 Jul; 115(7): 1035–1039.

[13] Luo N, Pereira S, Sahin O, Lin J, Huang S, Michel L, Zhang Q. Enhanced *in vivo* fitness of fluoroquinolone-resistant *Campylobacter jejuni* in the absence of antibiotic selection pressure. Proc Natl Acad Sci U S A. 2005 Jan 18;102(3):541-6.

Figure 1. 15 Ciprofloxacin resistance in *Campylobacter* isolates from chicken varies over time and between regions, CIPARS 2011 to 2016



Data sources: Human isolates for Ontario and Prairie region are from FoodNet Canada.

Integrated antimicrobial use and resistance data

Ceftriaxone resistance in non-typhoidal *Salmonella* and generic *E. coli*

Ceftriaxone is a Category I antimicrobial[14] (very high importance to human medicine) that is used to treat a variety of human infections. Although ceftriaxone is not used in animals, other similar drugs (e.g., ceftiofur) are used to treat and prevent a range of animal infections. In most situations, if an organism is resistant to one of these drugs it will also be resistant to the other.

In mid-2014, the poultry industry implemented a national ban on the use of Category I antimicrobials for disease prevention purposes[15]. Consistent with the timing of this ban, reported ceftiofur use in broiler chickens decreased and dropped to 0% among participating flocks in 2015. Reported ceftiofur use remained at 0% in 2016. Over the same time period, a concurrent decline was observed in resistance to ceftriaxone in *Salmonella* from multiple surveillance components (Figure 1. 16). Similar trends have been observed in *E. coli* (Figure 1. 17). Most ceftriaxone resistance in humans has been observed in isolates of *Salmonella* Heidelberg. In 2016, resistance to ceftriaxone in *Salmonella* Heidelberg isolates from humans dropped to 16%, down from 27% in 2015.

The industry-led initiative to eliminate use of ceftiofur and all other Category I antimicrobials in poultry for disease prevention appears to have had the desired effect. Data have shown a reduction in reported use of ceftiofur in broiler chicken as well as reduced resistance in both *E. coli* and *Salmonella* from chickens and chicken meat. This trend will be monitored in coming years and the impact of this important intervention on resistance in *Salmonella* from humans will also continue to be examined.

[14] Category I antimicrobials are classified by Health Canada to be of very high importance to human medicine. Available at: https://www.canada.ca/en/health-canada/services/drugs-health-products/veterinary-drugs/antimicrobial-resistance/categorization-antimicrobial-drugs-based-importance-human-medicine.html. Accessed July 2018.

[15] Chicken Farmers of Canada. AMU Strategy – A Prescription for Change. Available at: http://www.chickenfarmers.ca/wp-content/uploads/2018/01/AMU-Magazine_ENG_web-2.pdf. Accessed February 2018.

Figure 1. 16 Reduction in reported use of ceftiofur on farm and changing resistance to ceftriaxone in non-typhoidal *Salmonella* from humans and chicken sources, CIPARS 2003 to 2016

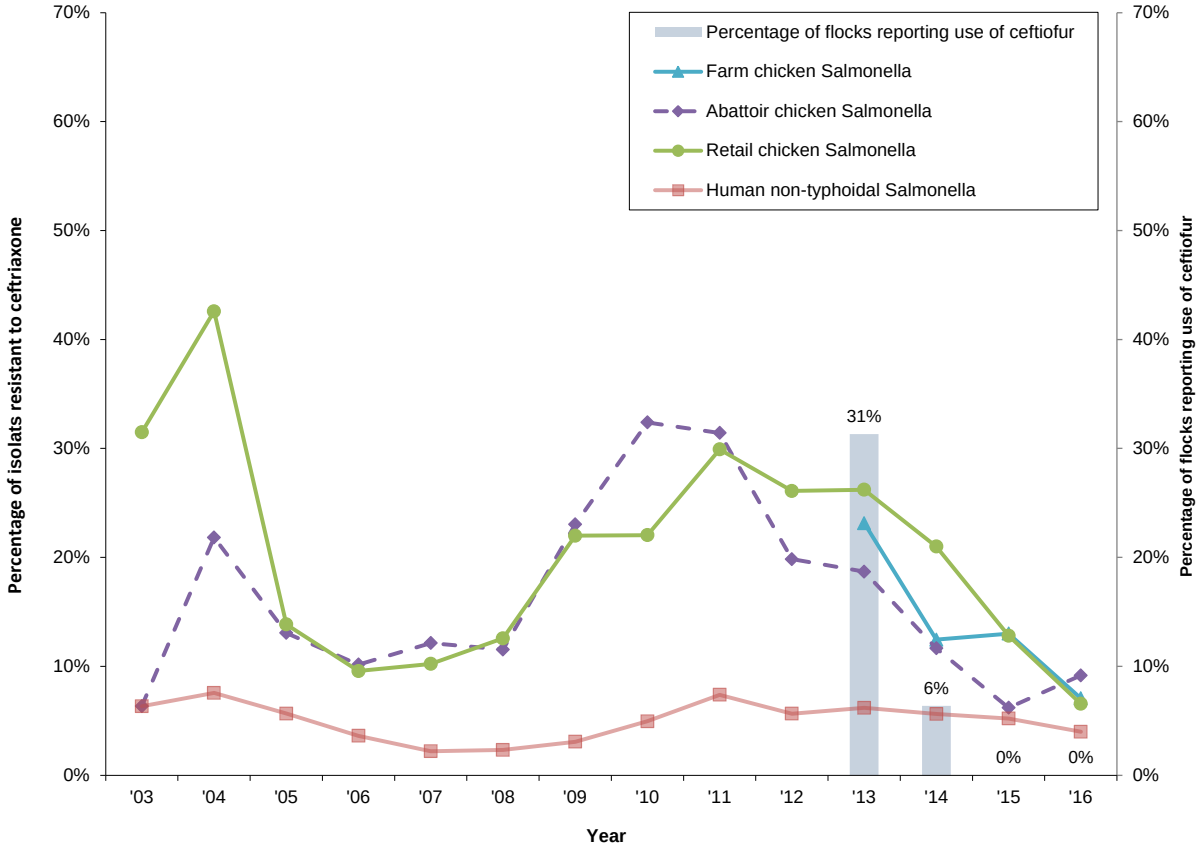
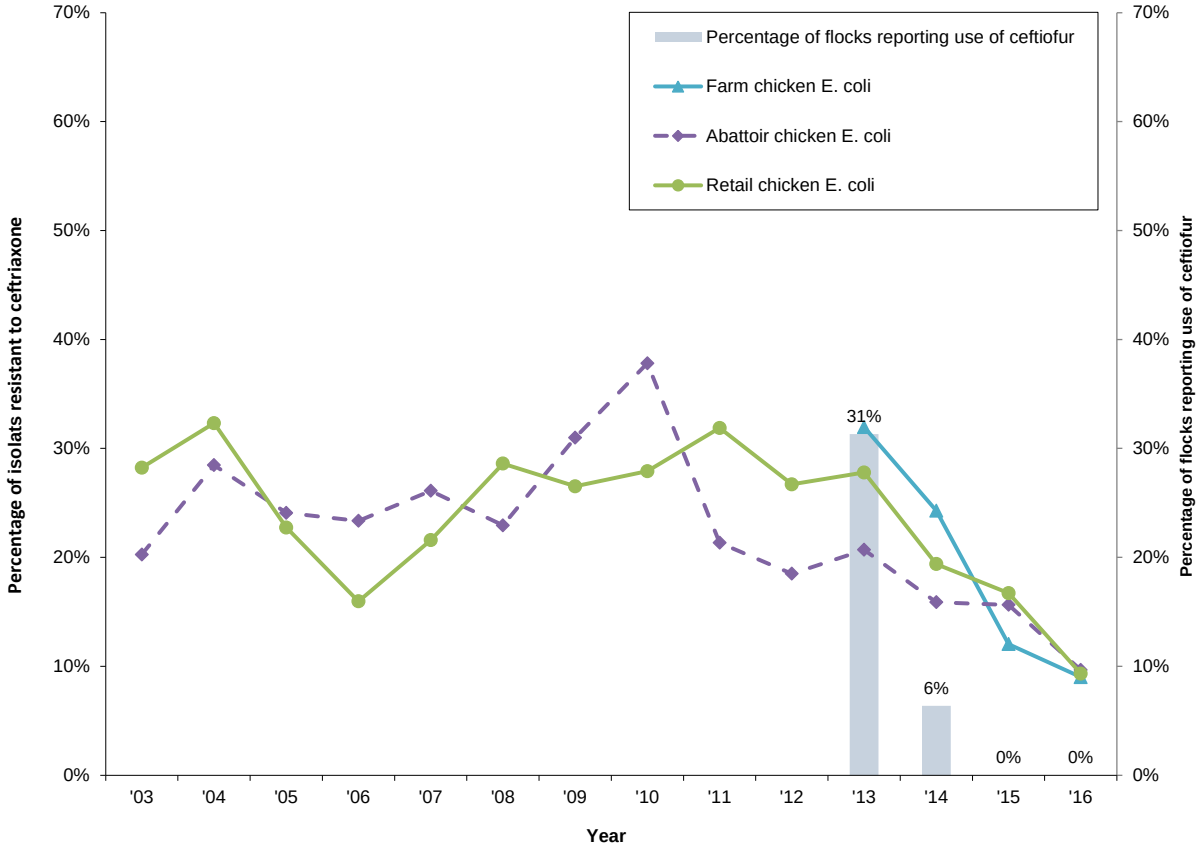


Figure 1. 17 Reduction in reported use of ceftiofur on farm and changing resistance to ceftriaxone in *Escherichia coli* from chicken sources, CIPARS 2003 to 2016



The reduction in use of ceftiofur and associated reduction in ceftriaxone resistance in chickens and humans is a great success story for the poultry industry. However, new data suggest that this change in use practice may have created a situation where new use practices were implemented and new resistance (i.e., gentamicin resistance) patterns emerged.

Increasing gentamicin resistance

In 2016, an increase in gentamicin resistance was observed in multiple CIPARS surveillance components including human *Salmonella* isolates, for the second straight year. In humans, most of the resistance to gentamicin has been observed in isolates of *S.* Heidelberg and *S.* 4,[5],12: i:-. In 2016, 60 *Salmonella* isolates from humans were resistant to gentamicin: 26 isolates of *S.* Heidelberg, 15 isolates of *S.* 4,5,12:i:-, and 10 other serovars (6 *S.* Kentucky, 3 *S.* Infantis and 1 *S.* 4,5,12,27:H). The human *Salmonella* isolates appear to be equally distributed across Canada.

Although there is minor variation, much of the increase in resistance in agri-food sectors has been in poultry and mainly in *E. coli;* few *Salmonella* isolates have demonstrated resistance to gentamicin. As a result, the focus of the following section will be on *E. coli* and chickens.

At retail, gentamicin resistance was observed in *E. coli* isolates recovered from chicken across all regions sampled. The highest resistance levels were observed in Québec and British Columbia and both provinces showed significantly higher levels of resistance in 2016 than in 2015. At abattoir, there has been an increasing trend in gentamicin resistance in *E. coli* isolates from chicken since 2015. As observed at retail, the highest levels of resistance were observed in Québec in 2016. At the farm level, *E. coli* recovered from chicken (pre-harvest) showed a slight increase in gentamicin resistance overall (19% in 2015 to 21% in 2016). However, the level of and trends in resistance vary by region. In 2016, gentamicin resistance increased in Ontario but decreased in British Columbia and Québec.

The link between gentamicin resistance and antimicrobial use appears to involve both gentamicin use as well as lincomycin-spectinomycin use. Use of gentamicin in hatcheries was reported occasionally from British Columbia, the Prairies and Ontario but has not been reported in Quebec hatcheries (Figure 3. 27). In 2016, gentamicin use was reported by 3 hatcheries, 1 in each of British Columbia, Saskatchewan and Ontario; this use corresponded to 4 CIPARS flocks being exposed to gentamicin (2 in British Columbia, 1 in Saskatchewan and 1 in Ontario). Lincomycin-spectinomycin was commonly used in broiler hatcheries in Québec and was occasionally reported from other regions as well (Figure 3. 27). In 2016, lincomycin-spectinomycin use was reported by 6 hatcheries (2 in British Columbia, 1 in Alberta, and 3 in Québec); this corresponded to 27 flocks with exposure to this drug (1 in British Columbia, 1 in Alberta, 2 in Ontario and 23 in Québec). Co-selection between the use of lincomycin-spectinomycin and gentamicin resistance has been reported previously[16].

To examine the relationship between ceftriaxone and gentamicin resistance, as well as ceftiofur, gentamicin and lincomycin-spectinomycin use, we created Figure 1. 17, Figure 1. 18 and Figure 1. 19. Figure 1. 18 replicates Figure 1. 17, but is limited to the data from the last 5 years and gentamicin and lincomycin-spectinomycin use have been added. Figure 1. 19 replicates Figure 1. 18 with the addition of trends in resistance to gentamicin from chicken on farm, at slaughter and at retail.

[16] Chalmers G, Cormier AC, Nadeau M, Côté G, Reid-Smith RJ, Boerlin P. Determinants of virulence and of resistance to ceftiofur, gentamicin, and spectinomycin in clinical *Escherichia coli* from broiler chickens in Québec, Canada.2017. Veterinary Microbiology; 203 (2017): 149–157).

Figure 1. 18 Trends in reported use of ceftiofur, gentamicin and lincomycin on farm (hatchery) and changing resistance to ceftriaxone in *Escherichia coli* from chicken sources, CIPARS 2012 to 2016

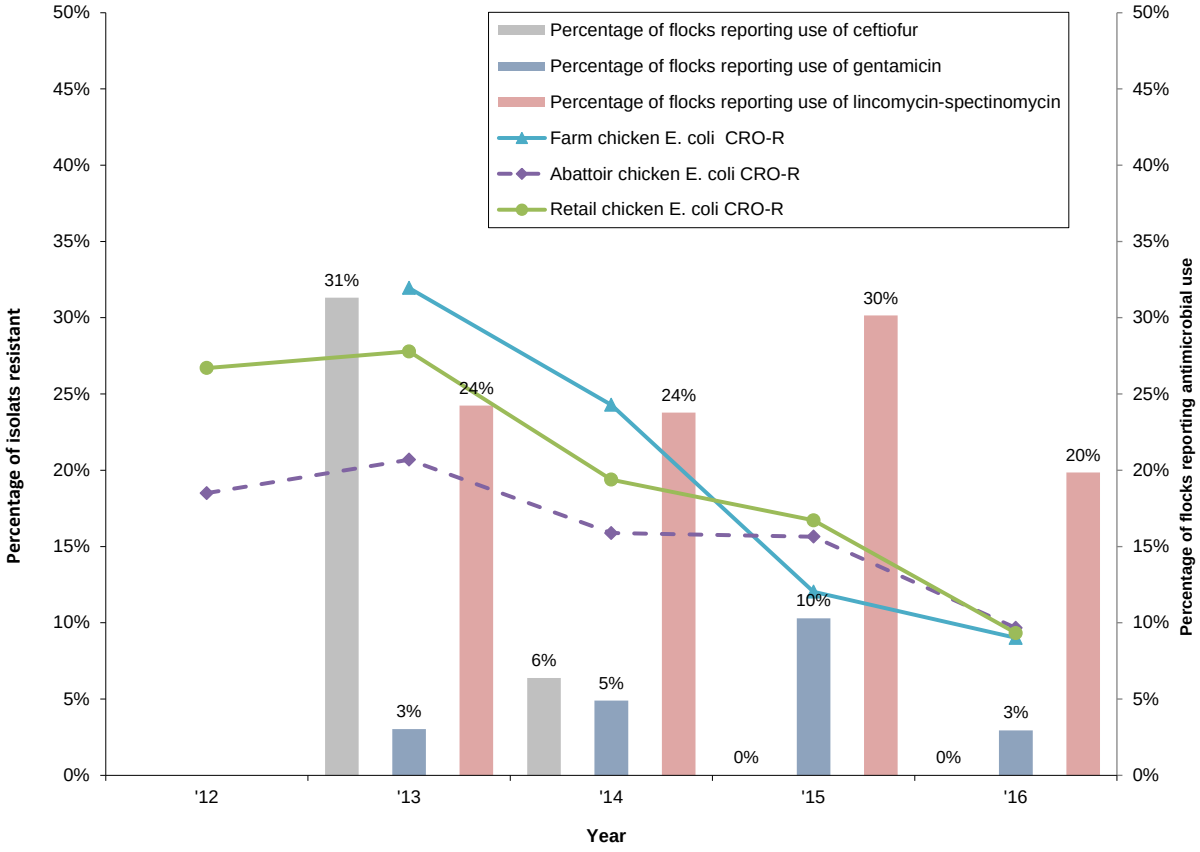
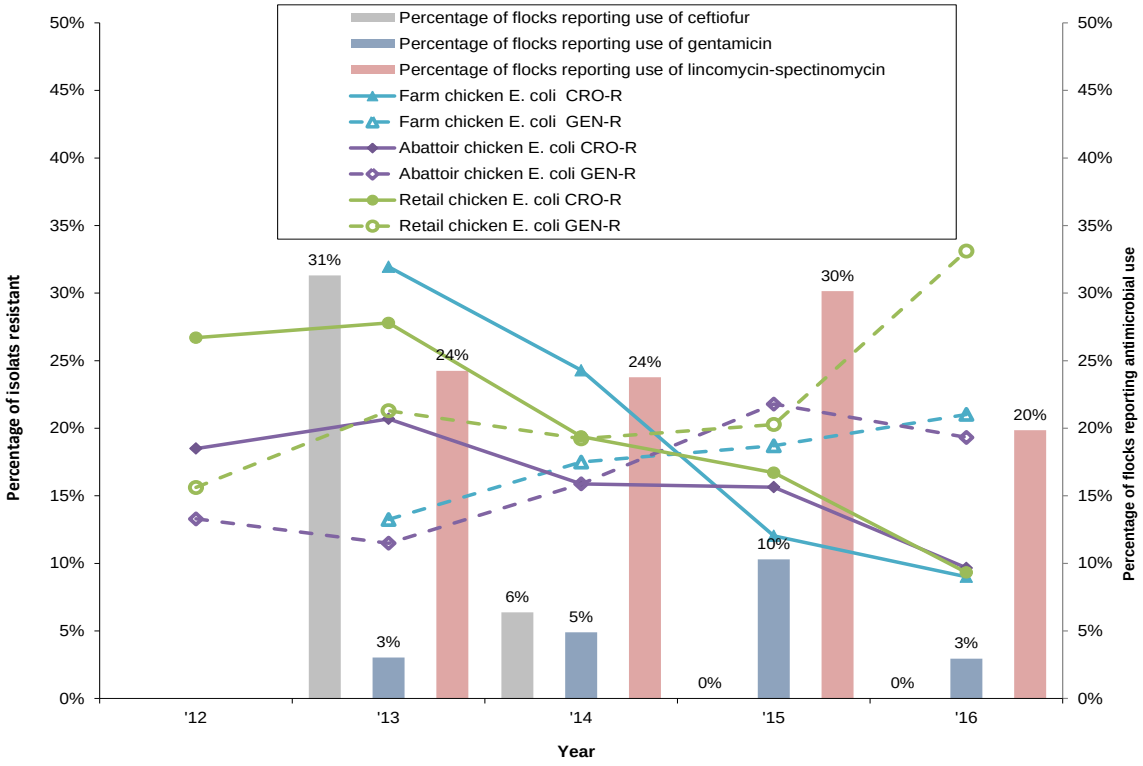


Figure 1. 19 Trends in reported use of ceftiofur, gentamicin and lincomycin on farm (hatchery) and changing resistance to ceftriaxone and gentamicin in *Escherichia coli* from chicken sources, CIPARS 2012 to 2016



In summary, it appears that the preventive use of ceftiofur to reduce the incidence of *E. coli* omphalitis and other conditions in young chicks has been replaced with the use of other antimicrobials including gentamicin and lincomycin-spectinomycin. In parallel with the change in use practices, we have observed changing resistance profiles among the isolates recovered from chickens and chicken meat. Both lincomycin-spectinomycin and gentamicin are Category II antimicrobials of high importance to human medicine. The poultry industry in Canada has committed to removing the preventive use of Category II antimicrobials by the end of 2018[17]. In 2016, a reduction in the proportion of participating broiler flocks exposed to these Category II antimicrobials was already observed: gentamicin use dropped from 10% in 2015 to 3% in 2016 and lincomycin-spectinomycin use dropped from 30% to 20%. Based on this, a further reduction in use of these 2 antimicrobials in 2017 and 2018 should be expected. CIPARS will monitor the effect of these changing use practices on resistance. Beyond 2018, the poultry industry has set a goal to eliminate the preventive use of Category III antimicrobials by the end of 2020[18].

[17] Chicken Farmers of Canada. AMU Strategy: A Prescription for Change. Available from: http://www.chickenfarmers.ca/wp-content/uploads/2018/01/AMU-Magazine_ENG_web-2.pdf. Accessed February 2018.

[18] Chicken Farmers of Canada. AMU Strategy: A Prescription for Change. Available from: http://www.chickenfarmers.ca/wp-content/uploads/2018/01/AMU-Magazine_ENG_web-2.pdf. Accessed February 2018.

Chapter 2 Animal health status and farm information

The data presented in this section pertains to pertinent farm-level animal health status and CIPARS sentinel farm information for broiler chickens, turkeys and grower-finisher pigs. These are relevant to antimicrobial use and antimicrobial resistance.

Broiler chickens

Key findings

Mortality

The mortality rate in the broiler flocks surveyed was similar to the previous year (median: 3%, range 1 to 13%).

Chick sources

Information on the chicks/hatching egg sources was also collected. This operational factor has been hypothesized as a risk factor for the presence of zoonotic enteric pathogens and antimicrobial-resistant bacteria harmful to people[19,20].

Overall, the total number of chicks placed in the sampling unit (barn/floor/pen sampled for microbiological testing) in 2016 was similar to the previous years and comprised of 84% domestic, 14% imported and 1% from other provinces (Figure 2. 1). The number of producers reporting domestic origin was 89% (121/136 flocks); regionally, the number of producers reporting imported origin was highest in the Prairies (32%, 12/38 flocks) (Figure 2. 2). The proportion of imported chicks placed in the barn sampled ranged from 3% to 100%, depending on the province/region.

Diagnosis of disease in broiler flocks

Diseases associated with avian pathogenic *E. coli* (APEC) were reported across all provinces/region. Overall, yolksacculitis and septicemia were diagnosed in 24 flocks and 14 flocks, respectively; the diagnosis of septicemia was highest in Ontario similar to the previous years (Figure 2. 3). Another APEC-associated disease, airsacculitis, was diagnosed in 8 flocks. The diagnosis of APEC-associated localized and systemic diseases may partially explain the usage of antimicrobials for treatment purposes (e.g., trimethoprim and sulfonamides in feed and sulfonamides in water) and preventive use of gentamicin and lincomycin-spectinomycin at the hatcheries. Currently, the use of alternative products to manage APEC (e.g., *E. coli* vaccine described in the last paragraph) slightly increased by 2% (8 flocks in 2015 to 11 flocks in 2016).

[19] Agerso et al. 2014. Spread of extended spectrum cephalosporinase-producing *Escherichia coli* clones and plasmids from parent animals to broilers and to broiler meat in a production without use of cephalosporins. Foodborne Pathogens and Disease 11:740-746. Available at: http://online.liebertpub.com/doi/pdf/10.1089/fpd.2014.1742. Accessed October 2016.

[20] Nilsson O. 2014. Vertical transmission of *Escherichia coli* carrying plasmid-mediated AmpC (pAmpC) through the broiler production pyramid. Journal of Antimicrobial Chemotherapy. 69:1497-1500. Available at: http://jac.oxfordjournals.org/content/69/6/1497.full.pdf+html. Accessed October 2016.

Occasional diagnosis of necrotic enteritis, salmonellosis, vertebral osteomyelitis (*Enterococcus cecorum*), other bacterial or mixed bacterial infections and coccidiosis were reported (Figure 2. 3). The relatively stable number of flocks diagnosed with enteric diseases such as necrotic enteritis and coccidiosis could be explained, in part, by the routine preventive use of antimicrobials and coccidiostats. As in APEC, there are limited non-antimicrobial alternatives to manage these enteric diseases.

Overall, the proportion of flocks diagnosed with any of the viral diseases (Figure 2. 4) affecting broilers in Canada remained relatively low; however, in Québec, there were flocks diagnosed with Inclusion Body Hepatitis (n = 1), Infectious Bronchitis (n = 4) and Infectious Bursal Disease (n = 6). The generally low frequency of flocks diagnosed with viral infections could be explained, in part, by the widespread use of vaccines against these viral diseases and that cases occurred outside of our surveillance timeframe/flock selection. We encourage readers to consult recent reports of diseases prevalent (e.g., emerging Infectious Bronchitis Virus, Delmarva strain and Reovirus infections) in the province/region and other animal health issues in the field[21].

Biosecurity

Median downtime (period between 2 flock cycles) was 16 days (range: 5 to 54 days). Other biosecurity information[22] was collected and data are available on request. These other data include but are not limited to disinfection, cleaning, water treatment, and manure management practices.

Zootechnical additives and vaccines

Ninety-two percent (125/136) of flocks were vaccinated against viral diseases at the hatchery. Infectious Bronchitis Virus (IBV), (85%, 115/136) was most frequently applied vaccine followed by Marek's disease (Herpesvirus of turkeys: 41% [56/136 flocks] and Marek's Disease-IBD vectored vaccine: 37% [50/136 flocks]).

After chick placement, 26% (36/136) of flocks were vaccinated. The most frequently used vaccines were IBD (20%, 27/136 flocks) and IBV (Massachusetts strain: 7% [9/135 flocks] and Massachusetts-Connecticut strains: 4% [5/136 flocks]).

The use of bacterial vaccines/bacterins were also reported. *Escherichia coli* vaccine[23] was administered at the hatchery in 8% of the flocks [11/136 flocks] while the *Salmonella* vaccine[24] was hatchery administered in 4% of the flocks (5/136 flocks) and farm administered in 1% of the flocks (1/136 flocks).

Coccidiosis vaccine, applied to 10% (13/136) of flocks at the hatchery involved flocks that were reared under the "raised without antibiotics (RWA)" program, also known as antibiotic-free program (ABF). Flocks identified as RWA/ABF did not report any antibiotic, ionophore or chemical coccidiostat usage. However, in 2016, these flocks could have use chemical

[21] Ontario Animal Health Network. Available at: http://oahn.ca/networks/poultry/. Accessed August 2017.

[22] CFIA 2009. National On-Farm Avian Biosecurity Standard. Available at: http://www.inspection.gc.ca/DAM/DAM-animals-animaux/STAGING/text-texte/terr_biosec_avian_standard_1375192173847_eng.pdf. Accessed July 2016.

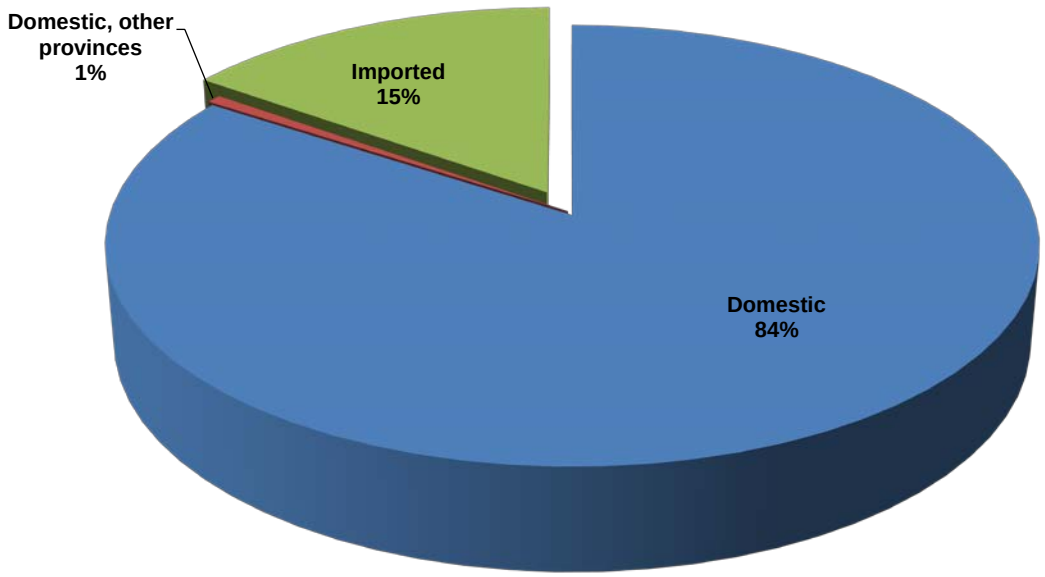
[23] Labelled for the prevention of APEC infections. Available at: https://bam.cvpservice.com/product/view/1198436. Accessed December 2016. This is a live *aroA* gene deleted *Escherichia coli*, type O78.

[24] Live culture *Salmonella* Typhimurium vaccine. Available at: https://bam.cvpservice.com/product/view/1198460. Accessed May 2017.

coccidiostats, but not ionophores or antibiotics[25]. Flocks identified as ABF-transitional flocks are also reducing AMU by rotating in and out antibiotics to control coccidiosis.

Zootechnical additives (acidifiers, probiotics, prebiotics, and essential oils) were used in 1 to 4% of the flocks sampled in 2016. Detailed vaccination information and zootechnical additives (temporal analysis) are available upon request.

Figure 2. 1 Relative distribution of chick sources, 2016



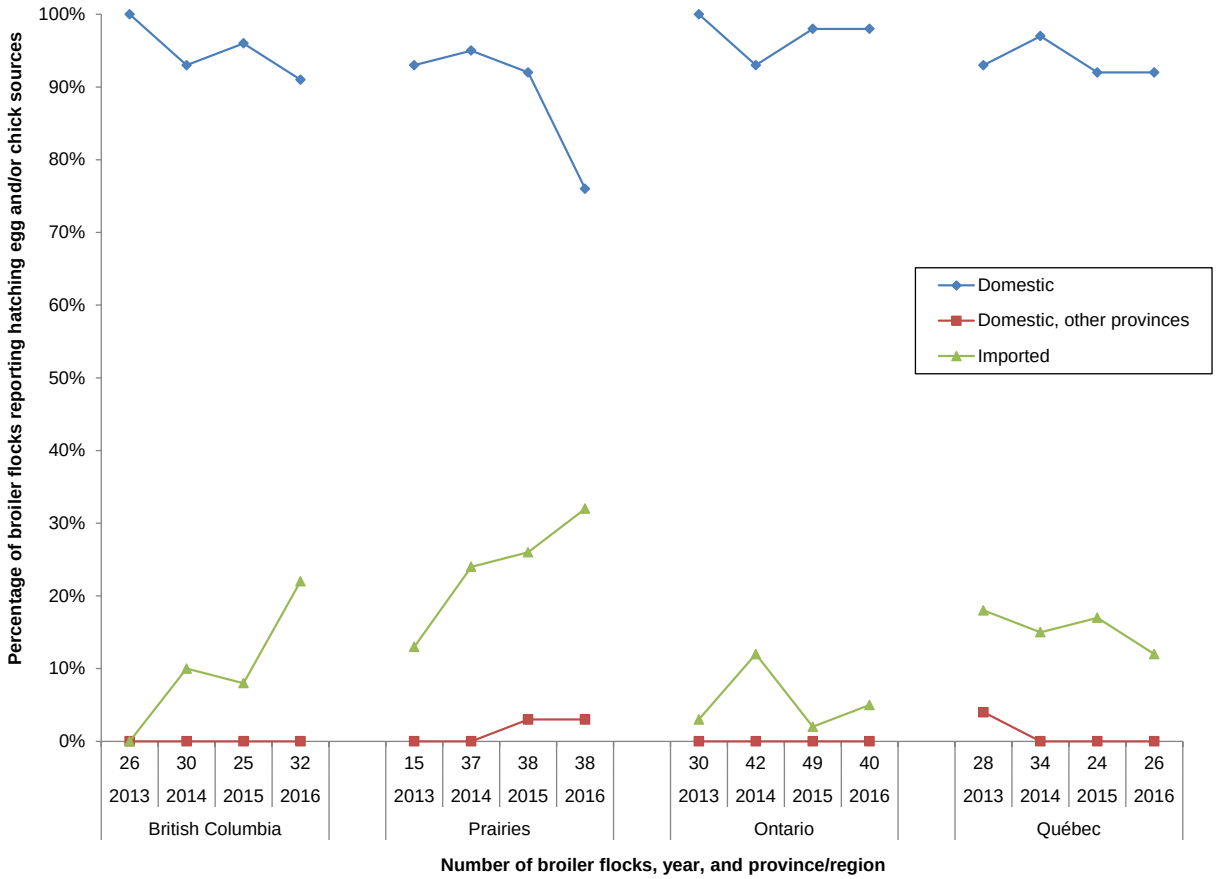
Domestic chicks = hatched within the province where the birds were raised.

Domestic, other provinces = hatched in a different province from where the birds were raised.

Imported = hatching eggs and/or chicks were sourced by the importing hatchery from the United States or other countries.

[25] Canadian Food Inspection Agency 2016. "Raised without the use of antibiotics" claims. Available at: http://www.inspection.gc.ca/food/labelling/food-labelling-for-industry/method-of-production-claims/eng/1389379565794/1389380926083?chap=7#s6c7. Accessed December 2016.

Figure 2. 2 Sources of hatching eggs and/or chicks placed in the barn sampled by province/region, 2013 to 2016



Province/region	British Columbia				Prairies				Ontario				Québec			
Year	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016
Number of flocks	26	30	25	32	15	37	38	38	30	42	49	40	28	34	24	26
Hatching egg and/or chick sources																
Domestic	100%	93%	96%	91%	93%	95%	92%	76%	100%	93%	98%	98%	93%	97%	92%	92%
Domestic, other provinces	0%	0%	0%	0%	0%	0%	3%	3%	0%	0%	0%	0%	4%	0%	0%	0%
Imported	0%	10%	8%	22%	13%	24%	26%	32%	3%	12%	2%	5%	18%	15%	17%	12%

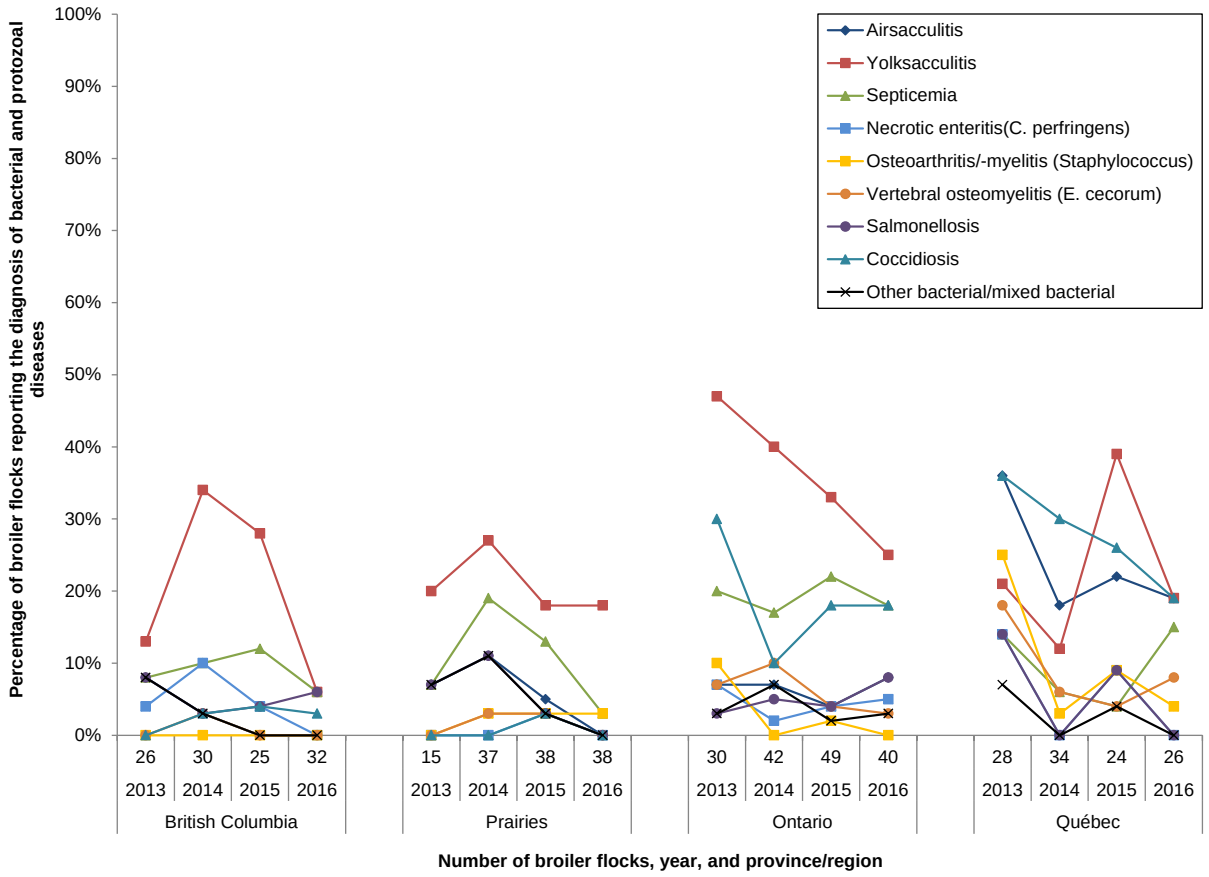
Domestic chicks = hatched from hatcheries located in the province where the birds were raised.

Domestic, other provinces = hatched from hatcheries located in provinces other than the province where the birds were raised.

Imported = hatching eggs and/or chicks were sourced by importing hatchery from the United States or other countries.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Figure 2. 3 Percentage of broiler flocks reporting bacterial and protozoal diseases by province / region, 2013 to 2016

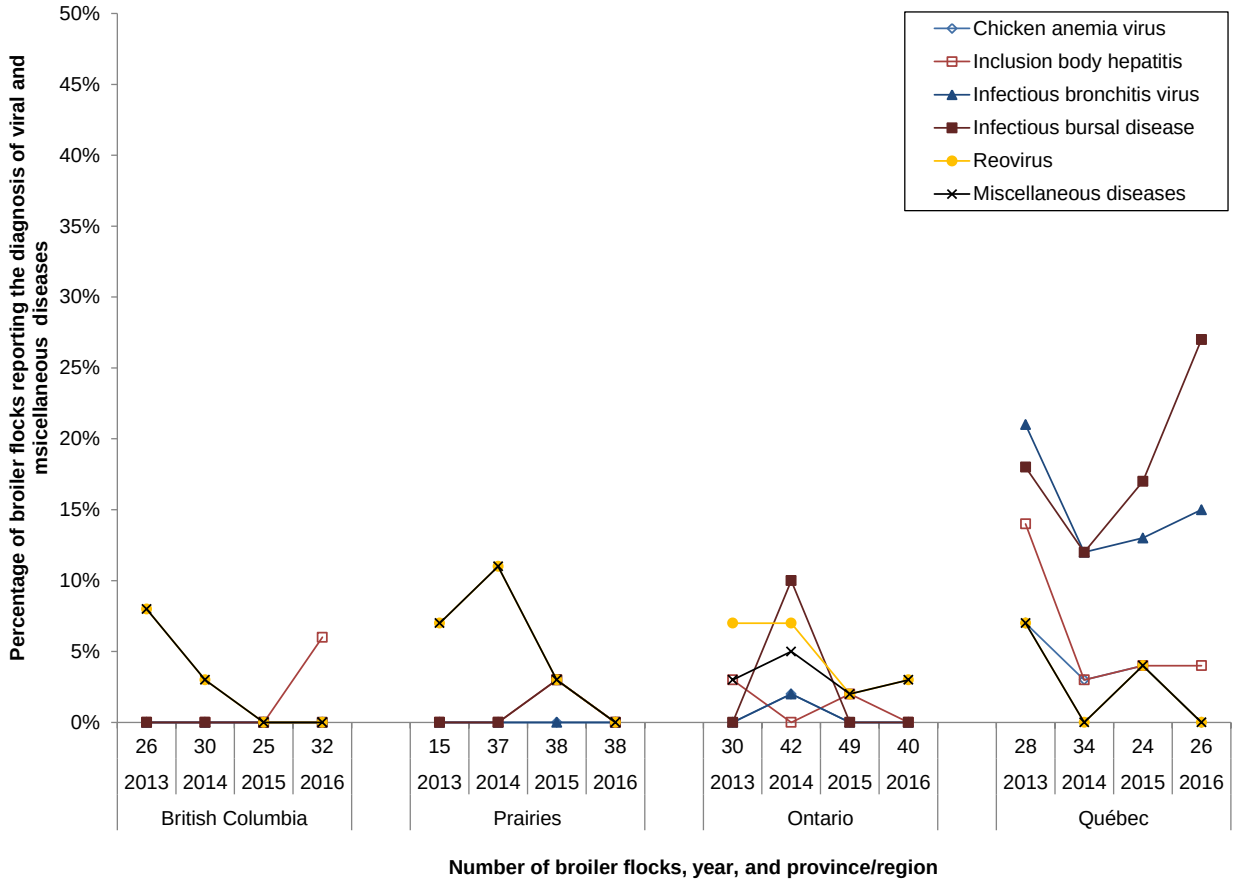


Province/region	British Columbia				Prairies				Ontario				Québec			
Year	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016
Number of flocks	26	30	25	32	15	37	38	38	30	42	49	40	28	34	24	26
Diseases																
Airsacculitis	8%	3%	0%	0%	7%	11%	5%	0%	7%	7%	4%	8%	36%	18%	22%	19%
Yolksacculitis	13%	34%	28%	6%	20%	27%	18%	18%	47%	40%	33%	25%	21%	12%	39%	19%
Septicemia	8%	10%	12%	6%	7%	19%	13%	3%	20%	17%	22%	18%	14%	6%	4%	15%
Necrotic enteritis (*C. perfringens*)	4%	10%	4%	0%	0%	0%	3%	0%	7%	2%	4%	5%	14%	0%	9%	0%
Osteoarthritis/osteomyelitis (*Staphylococcus*)	0%	0%	0%	0%	0%	3%	3%	3%	10%	0%	2%	0%	25%	3%	9%	4%
Vertebral osteomyelitis (*E. cecorum*)	0%	3%	0%	0%	0%	3%	3%	0%	7%	10%	4%	3%	18%	6%	4%	8%
Salmonellosis	8%	3%	4%	6%	7%	11%	3%	0%	3%	5%	4%	8%	14%	0%	9%	0%
Coccidiosis	0%	3%	4%	3%	0%	0%	3%	0%	30%	10%	18%	18%	36%	30%	26%	19%
Other bacterial/mixed bacterial	8%	3%	0%	0%	7%	11%	3%	0%	3%	7%	2%	3%	7%	0%	4%	0%

Health status was considered to be positive if the questionnaire response was "Confirmed positive" or "Likely positive" plus a response to any or combination of the following: clinical sign, post-mortem or laboratory testing to confirm the diagnosis. Health status was considered to be negative if the questionnaire response was "Confirmed negative" or "Likely negative". Data above was updated from previous year's data where only the flocks with confirmatory diagnosis were reported.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Figure 2. 4 Percentage of broiler flocks reporting the diagnosis of viral and miscellaneous diseases by province / region, 2013 to 2016



Province/region	British Columbia				Prairies				Ontario				Québec			
Year	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016
Number of flocks	26	30	25	32	15	37	38	38	30	42	49	40	28	34	24	26
Diseases																
Chicken anemia virus	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	0%	0%	7%	3%	4%	0%
Inclusion body hepatitis	0%	0%	0%	6%	0%	0%	3%	0%	3%	0%	2%	0%	14%	3%	4%	4%
Infectious bronchitis virus	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	0%	0%	21%	12%	13%	15%
Infectious bursal disease	0%	0%	0%	0%	0%	0%	3%	0%	0%	10%	0%	0%	18%	12%	17%	27%
Reovirus	8%	3%	0%	0%	7%	11%	3%	0%	7%	7%	2%	3%	7%	0%	4%	0%
Miscellaneous diseases	8%	3%	0%	0%	7%	11%	3%	0%	3%	5%	2%	3%	7%	0%	4%	0%

Health status was considered to be positive if the questionnaire response was “Confirmed positive” or “Likely positive” plus a response to any or combination of the following: clinical sign, post-mortem or laboratory testing to confirm the diagnosis. Health status was considered to be negative if the questionnaire response was “Confirmed negative” or “Likely negative”. Data above was updated from previous year’s data where only the flocks with confirmatory diagnoses were reported.

In 2016, miscellaneous diseases include femoral head necrosis (APEC suspected) and rickets.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Grower-finisher pigs

Key findings

Diagnosis of diseases in grower-finisher pig herds[26]

As in previous years, Québec had a higher proportion of herds with 7 or more diseases reported (44%) than Ontario (39%) and the Prairies (28%) (Figure 2. 5). *Mycoplasma* spp. was more common in Ontario (70%) and Québec (78%) than the Prairies (42%) (Figure 2. 6). Porcine circovirus associated disease (PCVAD) was more common in Ontario (92%) than the Prairies (66%) and Québec (70%) (Figure 2. 6). *Salmonella* was more common in Ontario (44%) and Québec (43%) than the Prairies (23%). *Erysipelas* trended upwards in all regions which is consistent with the Canadian Swine Health Information Network (CSHIN) report for 2016. *Hemophilus parasuis* was included on the questionnaire in 2016. It was most commonly reported in Ontario (89%) followed by the Prairies (73%) and Québec (63%).

Porcine Epidemic Diarrhea (PED) was also included on the questionnaire in 2016. There were no CIPARS grower-finisher herds in the 14 PED cases identified in Ontario in 2016. There were not any cases of PED in Québec or the Prairies in 2016 (CSHIN 2016)[27]. Diseases not included in the questionnaire that were reported in 2016 included *Actinobacillus suis* in 2 herds in the Prairies and *Brachyspira* in 1 herd in the Prairies.

Antibiotics were most commonly reported in grower-finisher herds in all 3 regions (Prairies, Ontario, and Québec) for the control or treatment of *Streptococcus suis* (34%, 26%, 30%) and *Lawsonia* (32%, 41%, 22%). Antimicrobials were more commonly reported for *Mycoplasma* in Ontario (33%) and Québec (26%) than in the Prairies (13%). However there was a substantial decrease in reported antimicrobial use for *Mycoplasma* in Québec between 2015 (52%) and 2016 (26%). In Québec, 26% of herds used antimicrobials for the treatment or control of swine influenza compared to 0% for Ontario (Figure 2. 7).

Grower-finisher pig herds in Ontario and Québec were significantly smaller than in the Prairies in 2016 (Figure 2. 10). As well, the number of pig farms within 2 km of CIPARS grower-finisher pig herds was significantly higher in Ontario and Québec than in the Prairies (Figure 2. 10).

Nursery pigs and sow herds

In 2016, there was an apparent decrease in the use of antimicrobials to treat or control *Streptococcus suis, Mycoplasma, Salmonella, E. coli, Lawsonia* and *Actinobacillus pleuropneumoniae* (APP) on Québec nurseries supplying CIPARS grower-finisher herds. There was also a decrease in reported use of antimicrobials for Mycoplasma in Ontario and the Prairies, and for *Lawsonia* in the Prairies. No nurseries supplying CIPARS grower-finisher herds were positive for PED.

In 2016, there appeared to be a higher reported use for *Erysipelas* in Ontario sow herds supplying CIPARS grower-finisher herds than in the other two regions although there was also an increase in the Prairies. Ontario continued to have the highest reported use of antimicrobials for the treatment or control of swine influenza in sow herds.

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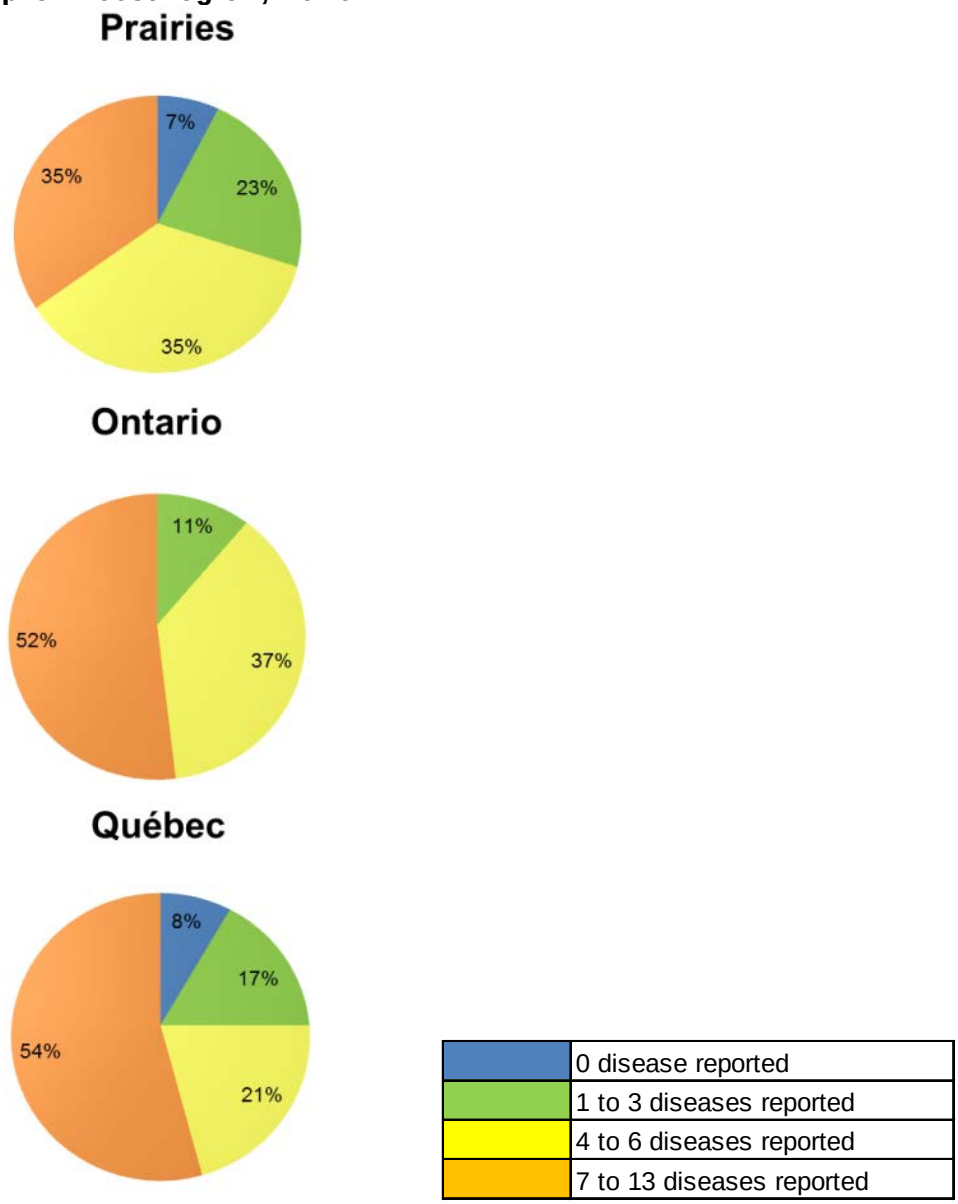
[26] For all statistical analyses, a *P*-value less than or equal to the level of significance of 0.05 ($P \leq 0.05$) was used to indicate a significant difference between years. All statistically significant results are marked by the use of the words “significant” or “significantly” in the text.

[27] Canadian Swine Health Intelligence Network (CSHIN) 2016 Producer Report. Available at: http://www.manitobapork.com/images/2016-Q4. Accessed on June 2018.

No sow herds supplying CIPARS grower-finisher herds were positive for PED.

Figure 2. 5 Number of infectious diseases reported by grower-finisher pig herds (n = 91) by provinces/region, 2016



Number of diseases is tabulated based on the 13 diseases listed on the questionnaire.

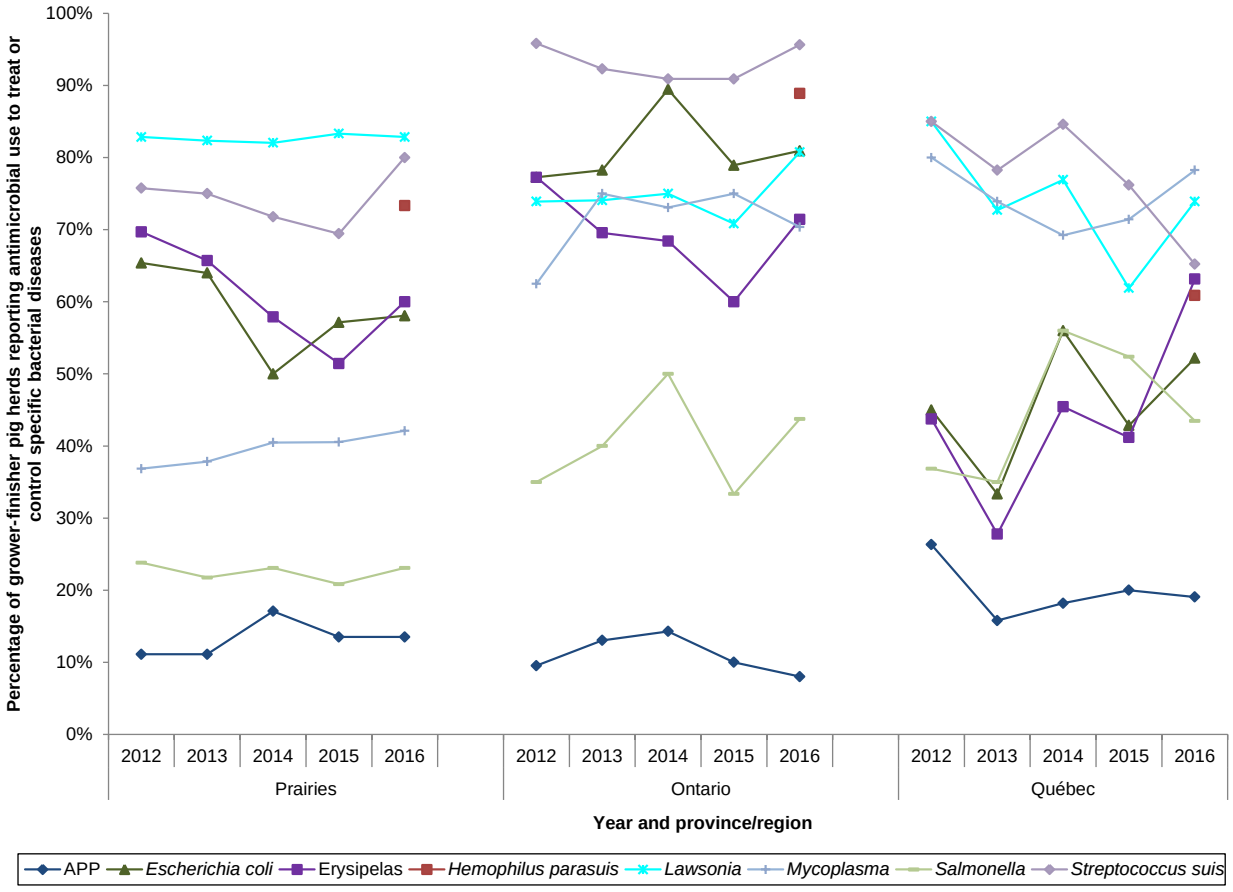
All farms in Ontario reported at least one disease on the questionnaire.

Health status was considered to be positive if the questionnaire response was “Confirmed positive” or “Likely positive”. Health status was considered to be negative if the questionnaire response was “Confirmed negative” or “Likely negative”.

The Prairies is a region including the provinces of Alberta, Saskatchewan, and Manitoba.

Figure 2. 6 Reported health status for diseases of grower-finisher pig herds by province / region, 2012 to 2016

a) Bacterial diseases



Province/region	Prairies					Ontario					Québec				
Year	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
Disease/bacteria															
APP	11%	11%	17%	14%	14%	10%	13%	14%	10%	8%	26%	16%	18%	20%	19%
Escherichia coli	65%	64%	50%	57%	58%	77%	78%	89%	79%	81%	45%	33%	56%	43%	52%
Erysipelas	70%	66%	58%	51%	60%	77%	70%	68%	60%	71%	44%	28%	45%	41%	63%
Hemophilus parasuis	NA	NA	NA	NA	73%	NA	NA	NA	NA	89%	NA	NA	NA	NA	61%
Lawsonia	83%	82%	82%	83%	83%	74%	74%	75%	71%	81%	85%	73%	77%	62%	74%
Mycoplasma	37%	38%	40%	41%	42%	63%	75%	73%	75%	70%	80%	74%	69%	71%	78%
Salmonella	24%	22%	23%	21%	23%	35%	40%	50%	33%	44%	37%	35%	56%	52%	43%
Streptococcus suis	76%	75%	72%	69%	80%	96%	92%	91%	91%	96%	85%	78%	85%	76%	65%

APP = *Actinobacillus pleuropneumoniae*.

Hemophilus parasuis, added to the questionnaire in 2016. NA = not available.

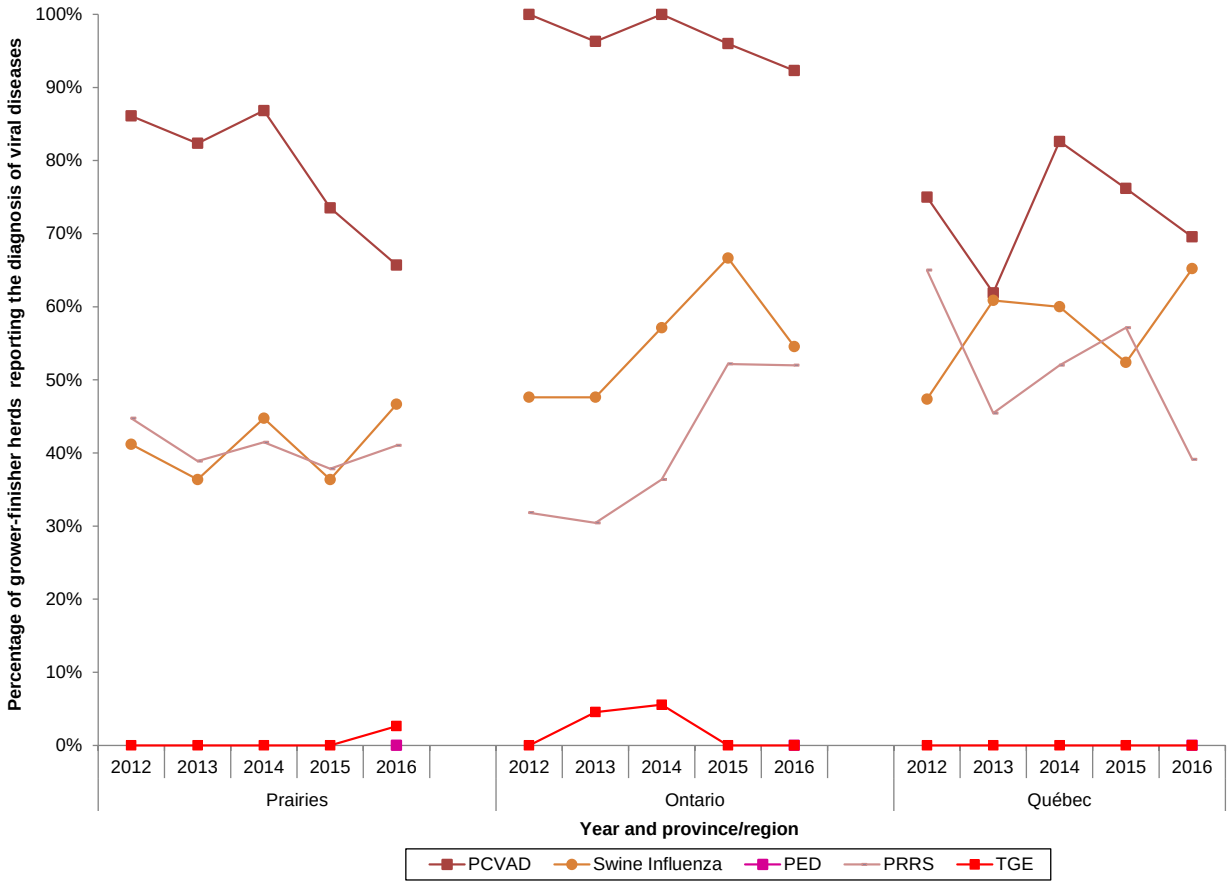
Health status was considered to be positive if the questionnaire response was “Confirmed positive” or “Likely positive”. Health status was considered to be negative if the questionnaire response was “Confirmed negative” or “Likely negative”.

Health status of nurseries and sow herds supplying CIPARS grower-finisher pig herds is available upon request.

The Prairies is a region including the provinces of Alberta, Saskatchewan, and Manitoba.

Figure 2. 6 Reported health status for diseases of grower-finisher pig herds by province / region, 2012 to 2016 (continued)

b) Viral diseases



Province/region	Prairies					Ontario					Québec				
Year	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
Disease/virus															
PCVAD	86%	82%	87%	74%	66%	100%	96%	100%	96%	92%	75%	62%	83%	76%	70%
Swine Influenza	41%	36%	45%	36%	47%	48%	48%	57%	67%	55%	47%	61%	60%	52%	65%
PED	NA	NA	NA	NA	0%	NA	NA	NA	NA	0%	NA	NA	NA	NA	0%
PRRS	45%	39%	41%	38%	41%	32%	30%	36%	52%	52%	65%	45%	52%	57%	39%
TGE	0%	0%	0%	0%	3%	0%	5%	6%	0%	0%	0%	0%	0%	0%	0%

PCVAD = Porcine Circovirus Associated Disease.

PED = Porcine Epidemic Diarrhea, added to the questionnaire in 2016. NA = not available.

PRRS = Porcine Reproductive and Respiratory Syndrome.

TGE = Transmissible Gastroenteritis.

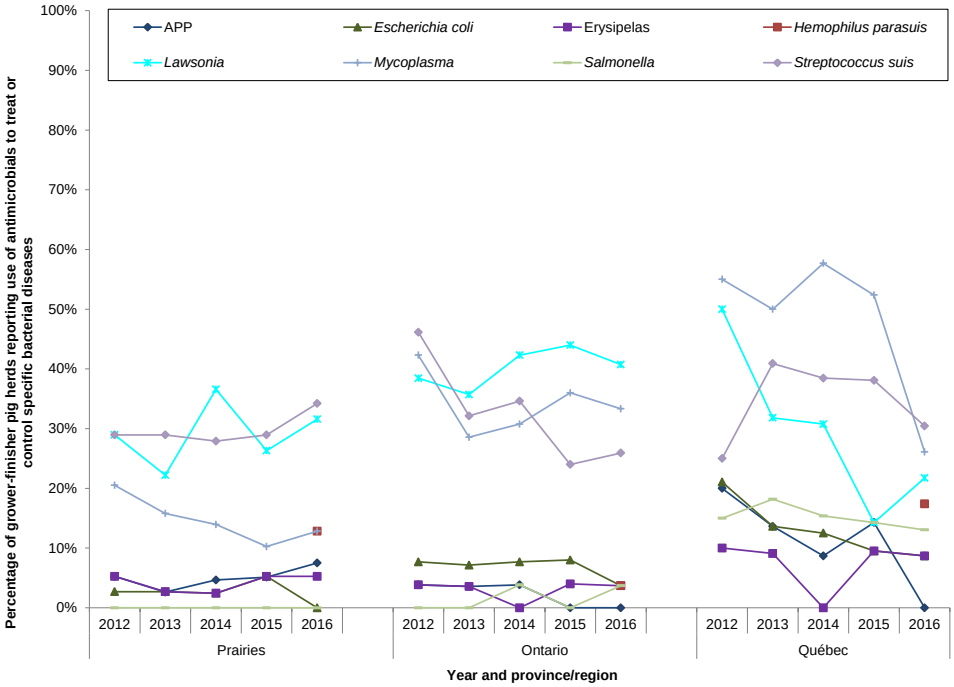
Health status was considered to be positive if the questionnaire response was “Confirmed positive” or “Likely positive”. Health status was considered to be negative if the questionnaire response was “Confirmed negative” or “Likely negative”.

Health status of nurseries and sow herds supplying CIPARS grower-finisher herds is available upon request.

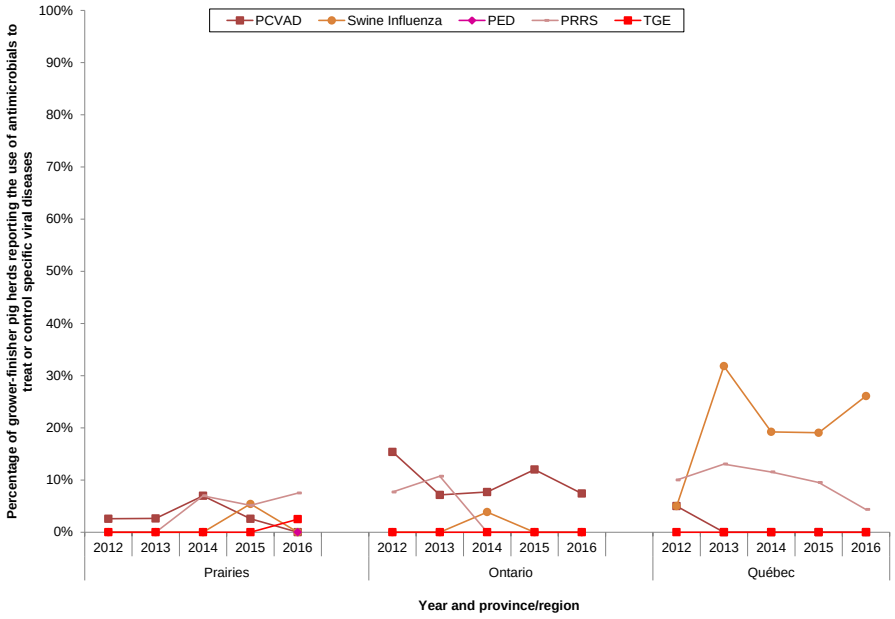
The Prairies is a region including the provinces of Alberta, Saskatchewan, and Manitoba.

Figure 2. 7 Reported antimicrobial use for specific diseases in grower-finisher pig herds by province / region, 2012 to 2016

a) Bacterial diseases



b) Viral diseases



See corresponding footnotes on next page.

Figure 2. 7 Reported antimicrobial use for specific diseases in grower-finisher pig herds by province / region, 2012 to 2016 (continued)

APP = *Actinobacillus pleuropneumoniae. Hemophilus parasuis*, added to the questionnaire in 2016.

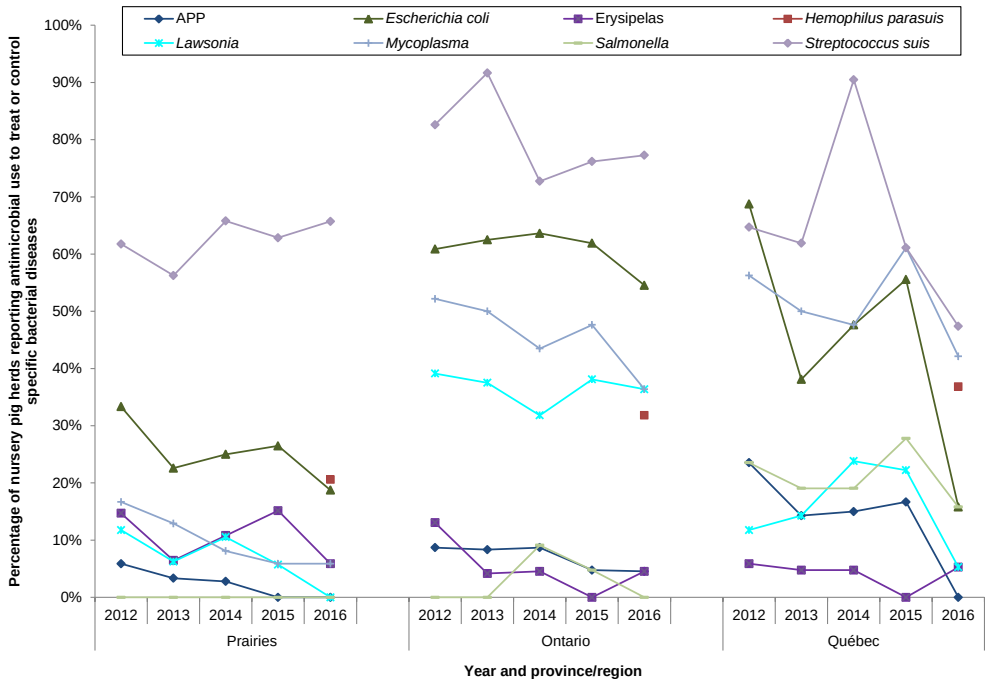
PCVAD = Porcine Circovirus Associated Disease. PED = Porcine Epidemic Diarrhea, added to the questionnaire in 2016. PRRS = Porcine Reproductive and Respiratory Syndrome. TGE = Transmissible Gastroenteritis.

Health status was considered to be positive if the questionnaire response was “Confirmed positive” or “Likely positive”. Health status was considered to be negative if the questionnaire response was “Confirmed negative” or “Likely negative”.

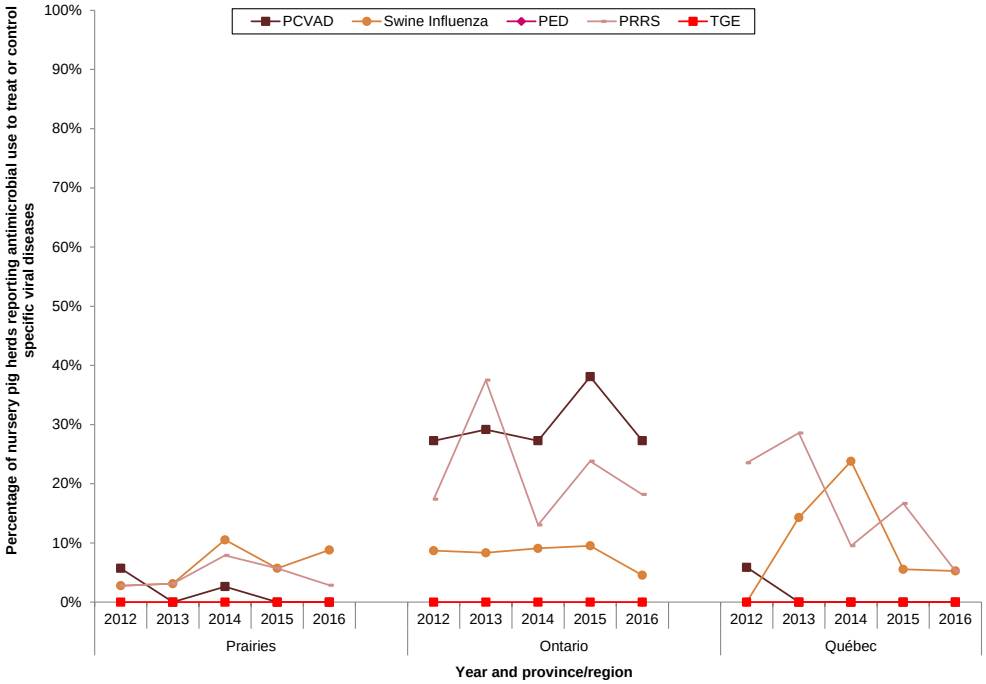
The Prairies is a region including the provinces of Alberta, Saskatchewan, and Manitoba.

Figure 2. 8 Reported antimicrobial use for specific diseases in nurseries supplying grower-finisher herds by province / region, 2012 to 2016

a) Bacterial diseases



b) Viral diseases



See corresponding footnotes on next page.

Figure 2. 8 Reported antimicrobial use for specific diseases in nurseries supplying grower-finisher herds by province / region, 2012 to 2016 (continued)

APP = Actinobacillus pleuropneumoniae. *Hemophilus parasuis*, added to the questionnaire in 2016.

PCVAD = Porcine Circovirus Associated Disease. PED = Porcine Epidemic Diarrhea, added to the questionnaire in 2016. PRRS = Porcine Reproductive and Respiratory Syndrome. TGE = Transmissible Gastroenteritis.

Not all questionnaires were completed for all diseases listed.

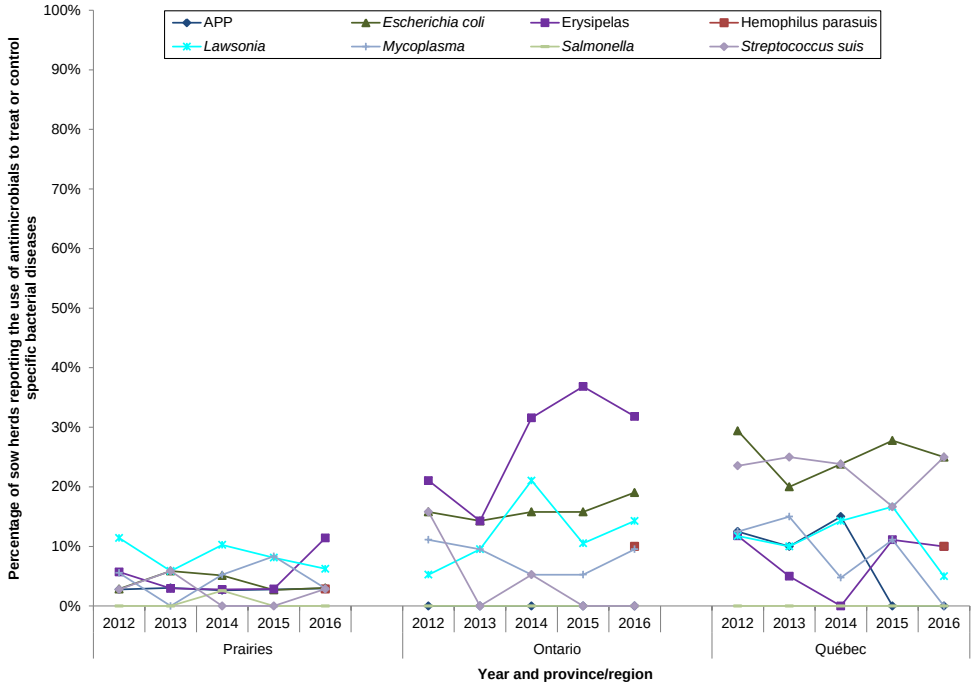
Health status was considered to be positive if the questionnaire response was “Confirmed positive” or “Likely positive”. Health status was considered to be negative if the questionnaire response was “Confirmed negative” or “Likely negative”.

There are 3 primary stages of pig production: suckling pigs (pre-weaning, in sow herds), nursery pigs (weaning to 25 kg), and grower-finisher pigs (25 kg to market weight). Data on antimicrobial use in suckling and nursery pigs is required to understand total antimicrobial exposure.

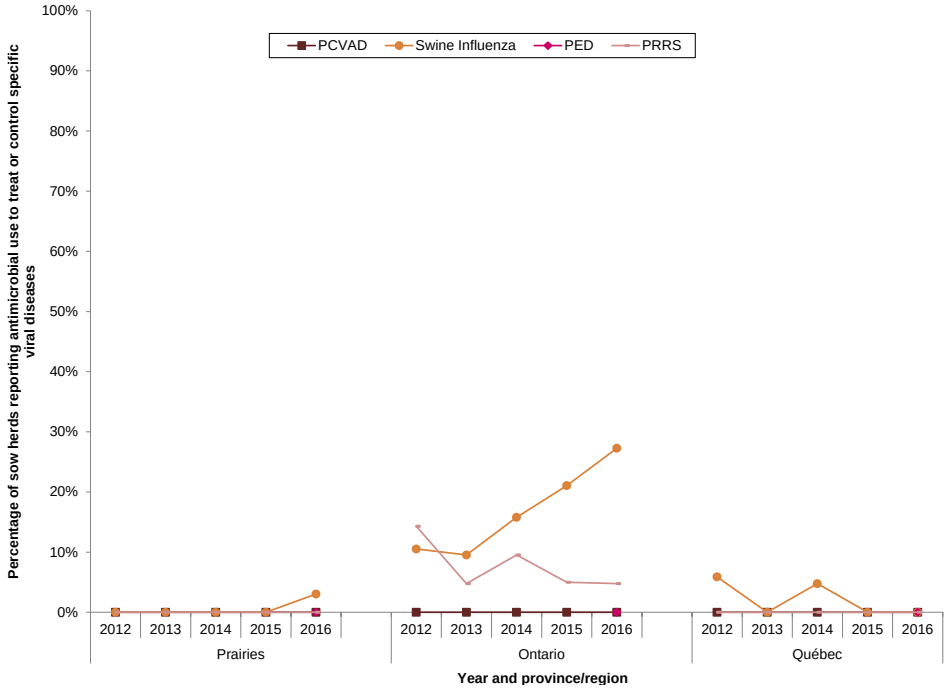
The Prairies is a region including the provinces of Alberta, Saskatchewan, and Manitoba.

Figure 2. 9 Reported antimicrobial use for specific diseases in sow herds supplying grower-finisher pig herds by province / region, 2012 to 2016

a) Bacterial diseases



a) Viral diseases



See corresponding footnotes on next page.

Figure 2. 9 Reported antimicrobial use for specific diseases in sow herds supplying grower-finisher pig herds by province / region, 2012 to 2016 (continued)

APP = *Actinobacillus pleuropneumoniae. Hemophilus parasuis*, added to the questionnaire in 2016. PCVAD = Porcine Circovirus Associated Disease. PED = Porcine Epidemic Diarrhea, added to the questionnaire in 2016. PRRS = Porcine Reproductive and Respiratory Syndrome. Transmissible Gastroenteritis (TGE) was not included in the sow herd survey.

Not all questionnaires were completed for all diseases listed.

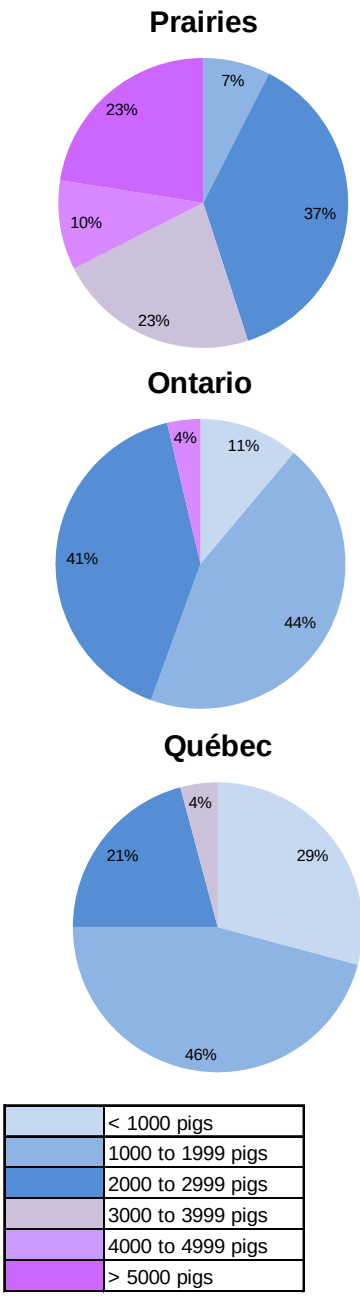
Health status was considered to be positive if the questionnaire response was “Confirmed positive” or “Likely positive”. Health status was considered to be negative if the questionnaire response was “Confirmed negative” or “Likely negative”.

There are 3 primary stages of pig production: suckling pigs (pre-weaning, in sow herds), nursery pigs (weaning to 25 kg), and grower-finisher pigs (25 kg to market weight). Data on antimicrobial use in suckling and nursery pigs is required in order to understand total antimicrobial exposure.

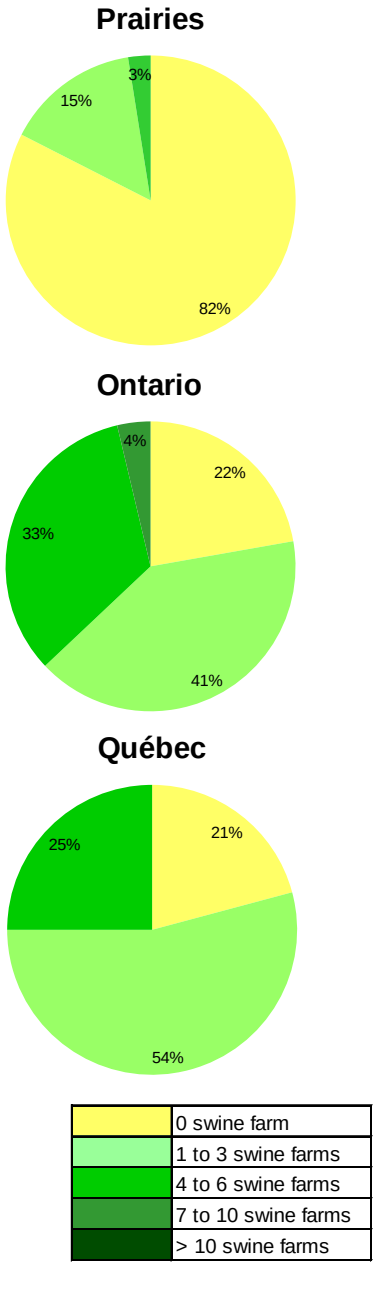
The Prairies is a region including the provinces of Alberta, Saskatchewan, and Manitoba.

Figure 2. 10 Demographics of grower-finisher pig herds by province / region (n = 91), 2016

a) Barn Capacity



b) Number of swine farms within 2 km



Capacity indicates the maximum number of pigs that the barn is designed to house.

Participating herds may have additional barns that were not sampled for the CIPARS program therefore this barn capacity is not necessarily equivalent to grower-finisher herd size.

The Prairies is a region including the provinces of Alberta, Saskatchewan, and Manitoba.

Turkeys

Key findings

Mortality

The median mortality rate in the 1 grow-out cycle of turkey flocks surveyed was 5% (range 1 to 30%).

Turkey poult sources

Overall, 43% of poults placed in 2016 were domestically sourced (hatchery located in province were the birds are raised), with 20% of birds reportedly sourced from other provinces (other than the province where the birds are raised) and 37% of poults were imported from the USA.

Diagnosis of diseases in turkey flocks

Avian pathogenic *E. coli* (APEC)-associated disease syndromes were the most frequently diagnosed, such as septicemia (13%), yolk sac infection (8%) and airsacculitis (6%). Enteric diseases such as necrotic enteritis (6%, Québec and Ontario) and coccidiosis (4%, flocks from Québec) were also reported.

Diagnosis of viral diseases was relatively uncommon. Only one producer reported the diagnosis of hemorrhagic enteritis.

Biosecurity

Median downtime (period between 2 flock cycles) was 14 days (range 1 to 240 days). Other biosecurity information[28] was collected and data are available upon request. These other data include but are not limited to disinfection, cleaning, water treatment, and manure management practices.

Zootechnical additives, vaccines, and deworming

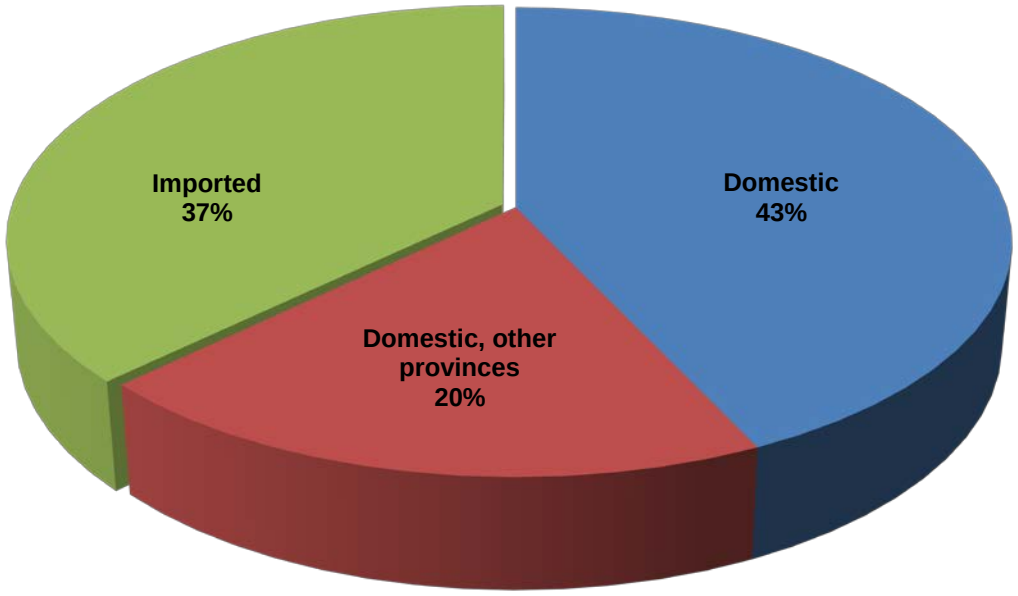
Seventy-one percent (51/72 flocks) of producers reported that their flocks were vaccinated with at least one viral/bacterial agent. Vaccine against Adenovirus II, the causative agent of Hemorrhagic Enteritis, was the most frequently administered vaccine (49%), followed by vaccine against Newcastle Disease Virus (NDV) combined with Marek's Disease Virus (14%) and vaccine against coccidiosis (13%). The latter vaccine was administered to turkey flocks that were raised without antibiotics and organic. Another NDV vaccination (booster) was administered to turkey flocks raised as heavy hens and heavy toms (13%).

[28] CFIA 2009. National On-Farm Avian Biosecurity Standard. Available at: http://www.inspection.gc.ca/DAM/DAM-animals-animaux/STAGING/text-texte/terr_biosec_avian_standard_1375192173847_eng.pdf. Accessed July 2016.

Seven percent (5/72) of turkey producers reported the use of fenbendazole[29] for treatment of internal parasitic infections[30]; these were largely administered to heavy toms/hens that are reared longer than broiler turkeys.

Zootechnical additives (acidifiers, probiotics, prebiotics, and essential oils) were used in 1 to 7% of the flocks sampled in 2016. Detailed vaccination information and zootechnical additives are available upon request.

Figure 2. 11 Relative distribution of turkey poult sources, 2016



Domestic = hatching eggs originated and/or poults hatched from hatcheries located in the province where the birds were raised.

Domestic, other provinces = hatching eggs originated and/or poults hatched from hatcheries located in provinces other than the province where the birds were raised

Imported = hatching eggs/poults were sourced by the importing hatchery from the United States or other countries; there were hatching eggs from domestic breeders hatched in United States hatcheries and then delivered/reared in Canadian turkey farms.

[29] Compendium of Veterinary Products. Fenbendazole. Available at: https://bam.cvpservice.com/product/view/1208165. Accessed June 2018.

[30] Fenbendazole, a benzimidazole derivative was known to target the cecal nematode *Heterakis gallinarum*, the carrier of blackhead organism, *Histomonas meleagridis* (Hegngi FN et al. Available at: https://doi.org/10.1016/S0304-4017(98)00233-7). Accessed June 2018.

Chapter 3 Antimicrobial use in animals

How to read this chapter

This chapter highlights the most notable antimicrobial use (AMU) findings across the animal surveillance components of CIPARS for 2016: quantities of antimicrobials distributed for sale for use in animals, AMU in broiler chickens (Farm Surveillance), AMU in grower-finisher pigs (Farm Surveillance), AMU in broiler chickens (Farm Surveillance) and for the first time in 2016, AMU in turkeys (Farm Surveillance).

Terms and definitions apply to this chapter

- **Metric:** also known as technical unit of measurement[31]; 3 different AMU metrics are used throughout this chapter including 1) frequency of use (counts of flocks/herds), 2) milligrams of antimicrobials consumed by the flocks/herds or total quantity (mg) of active ingredients distributed for sale and, 3) number (n) of Defined Daily Doses in animals (nDDDvet) using Canadian (CA) standards (DDDvetCA).
- **Indicator:** is defined as "a metric quantifying use of antimicrobials, usually expressed in relation to a denominator representing the population (at risk)"[32,33].
- **Dose:** is the recommended or veterinarian-prescribed milligrams of active ingredient administered per kilogram of the animal treated; dose information is indicated in the product label and are available from 2 Canadian references[34,35] or expert opinion[36].
- **Defined Daily Dose in animals (DDDvet) using Canadian (CA) doses (DDDvetCA):** the DDDvetCA standard is the average of all unique treatment and prevention label doses in milligrams per kg animal per day (unit: mg/kg per day). These are assigned by species. The DDDvetCA standards are listed in the Appendix (Table A. 1 and Table A. 2). These were developed using an approach similar to ESVAC's DDDvet assignment with some exceptions[37]. Details of the development of the standards are outlined in Chapter 5: Design and methods and will be included in an upcoming publication.

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[31] Collineau L, Belloc C, Stärk KD, Hémonic A, Postma M, Dewulf J, and Chauvin C. 2017. Guidance on the Selection of Appropriate Indicators for Quantification of Antimicrobial Use in Humans and Animals. Zoonoses Public Health, 64: 165-184.

[32] Collineau L, Belloc C, Stärk KD, Hémonic A, Postma M, Dewulf J, and Chauvin C. 2017. Guidance on the Selection of Appropriate Indicators for Quantification of Antimicrobial Use in Humans and Animals. Zoonoses Public Health, 64: 165-184.

[33] AACTING Consortium. Guidelines for collection, analysis and reporting of farm-level antimicrobial use, in the scope of antimicrobial stewardship. VERSION 1_2018-03-21. Available at: http://www.aacting.org/guidelines/. Accessed March 2018.

[34] Compendium of Veterinary Products. Available at: https://bam.cvpservice.com/. Accessed March 26, 2018.

[35] Compendium of Medicating Ingredients Brochure. Available at: http://www.inspection.gc.ca/animals/feeds/medicating-ingredients/eng/1300212600464/1320602461227. Accessed March 2018.

[36] Canadian Association of Poultry Veterinarians. CgFARAD. Available at: https://www.capv-acva.ca/cgfarad. Accessed March 2018.

[37] ESVAC. Principles on assignment of defined daily dose for animals (DDDvet) and defined course dose for animals (DCDvet). Available at: http://www.ema.europa.eu/docs/en_GB/document_library/Scientific_guideline/2015/06/WC500188890.pdf.

- • **Number of Defined Daily Doses (nDDDvetCA) in animals using Canadian standards (DDDvetCA):** is the total milligrams consumed by the flock/herd adjusted by the DDDvetCA standard. This metric is used in the 2 dose-based indicators presented in this report, nDDDvetCA/1,000 animal-days at risk and nDDDvetCA/PCU.
- **Population correction unit (PCU):** also known as animal biomass, is the total of all animals in the surveyed flock/herd (minus half of the mortalities) adjusted by the ESVAC standard body weight (e.g., 1 kg for broilers, 6.5 kg for turkeys, and 65 kg for grower-finisher pigs). For the national distribution data, this pertains to the number of livestock and/or slaughtered animals in each species/production stage adjusted by the ESVAC and Canadian standard body weight (Table A. 3 and Table A. 4).
- **Animal-days at risk:** also known as "standard-animals at risk"[38], is a denominator that accounts for the inter-species variations in live animal biomass and duration of the grow-out or observation period[39]. The "animal" component was calculated as above (i.e., total animals in the surveyed flock/herd minus half the mortalities multiplied by the ESVAC standard body weight) adjusted by the average days at risk or lifespan of the animal (e.g., broiler chickens = 34 days, grower-finisher pigs = 114 days, turkeys = 90 days). The average days at risk vary from year to year due to changes in production practices and other factors (e.g., diseases, genetics).

Quantitative data of the Farm Surveillance component

The quantitative component of the farm data is presented by route of administration (for broilers and turkeys only) and overall use using the following indicators:

- milligrams/PCU
- nDDDvetCA/1,000 animal-days at risk
- nDDDvetCA/PCU; presented for the first time in this report.

The AMU indicators nDDDvetCA/1,000 animal-days at risk and nDDDvetCA/PCU are used to better describe sample survey type of data where only a predetermined number of flocks/herds are surveyed each year, the animal population (flock/herd size) varies from year to year, and data is collected for a specified timeframe (i.e., only 1 production cycle or grow-out period per year). The mg/PCU, an indicator used in reporting quantities of antimicrobials distributed for sale at the national level[40], is also suggested for the reporting of farm-level data[41]. Table 3. 1 briefly describes the technical units of measurement and indicators used in this chapter. Detailed methodology are found in Chapter 5: Design and methods. We caution our readers that the scale (vertical axis) varies depending on the indicator, animal species or

[38] DANMAP. DANMAP 2016. Use of antimicrobial agents and occurrence of antimicrobial resistance in bacteria from food animals, food and humans in Denmark. Available at: https://www.danmap.org/~/media/Projekt%20sites/Danmap/DANMAP%20reports/DANMAP%20%202015/DANMAP%202015.ashx. Accessed March 2018.

[39] DANMAP. DANMAP 2016. Use of antimicrobial agents and occurrence of antimicrobial resistance in bacteria from food animals, food and humans in Denmark. Available at: https://www.danmap.org/~/media/Projekt%20sites/Danmap/DANMAP%20reports/DANMAP%20%202015/DANMAP%202015.ashx. Accessed March 2018.

[40] ESVAC. Sales of veterinary antimicrobial agents in 20 European countries in 2015. Trends from 2010 to 2015. Seventh ESVAC Report. Available at: http://www.ema.europa.eu/docs/en_GB/document_library/Report/2017/10/WC500236750.pdf. Accessed March 2018.

[41] EMA, 2018. Guidance on collection and provision of national data on antimicrobial use by animal species/ categories. EMA/489035/2016. Available at: http://www.ema.europa.eu/docs/en_GB/document_library/Scientific_ guideline/2017/03/WC500224492.pdf. Accessed March 2018.

route of administration; for example, in the broiler chicken and turkey sectors, the mg/PCU values for antimicrobials administered via water and injection were generally lower than the antimicrobials administered via feed.

Summary antimicrobial use data are presented in Table 3. 8, Table 3. 9, and Table 3. 10 for broiler chickens, in Table 3. 11, Table 3. 12, and Table 3. 13 for grower-finisher pigs and Table 3. 16, Table 3. 17, and Table 3. 18 for turkeys. All animal species have data for antimicrobials administered via feed. The broiler and turkey sections also summarize information for antimicrobials administered via water or injection. In this chapter, the data are presented by:

- **Antimicrobial (active ingredient):** counts of flocks or herds that used a specific antimicrobial active ingredient or did not use any antimicrobials; these are shown in the frequency figures and in the year-specific summary tables.
- **Antimicrobial class:** aggregated antimicrobial active ingredient data shown in the quantitative sections for each route of administration (feed, water, injection, if data are available) and the combined routes (for broiler chickens and turkeys only). The use indicators described on the next page, Table 3. 1, are presented by antimicrobial class).
- **Total antimicrobials used:** annual aggregated antimicrobial class data shown in the summary tables (broiler chickens: Table 3. 9 and, Table 3. 10 grower-finisher pigs: Table 3. 12; turkeys: Table 3. 17 and Table 3. 18).

To harmonize with other international surveillance programs[42,43] the figures and tables do not include the coccidiostats. These antimicrobial agents are described in a separate subsection (frequency of use in all commodities; quantitative summary for grower-finisher pigs) for farm data and as a separate section as kg active ingredients for the national distribution data. Detailed information pertaining to the on-farm use of these coccidiostats in broiler chickens and turkeys will be described in an upcoming publication.

[42] ESVAC. Sales of veterinary antimicrobial agents in 20 European countries in 2015. Trends from 2010 to 2015. Seventh ESVAC Report.

[43] DANMAP. Available at: https://www.danmap.org/~/media/Projekt%20sites/Danmap/DANMAP%20reports/DANMAP%20%202015/DANMAP%202015.ashx. Accessed March 2018.

Table 3. 1 Antimicrobial technical units of measurement and indicators used in this chapter

Indicator	Numerator	Denominator
Frequency of use	Number of flocks/herd exposed	Total flocks/herds sampled
$Percentage\ of\ flocks\ exposed/treated = \frac{Number\ of\ flocks\ or\ herds\ exposed}{Total\ flocks\ or\ herds\ sampled} \times 100$		
Frequency of rations	Number of medicated rations	Total number of rations
$Percentage\ of\ rations\ medicated = \frac{Number\ of\ rations\ medicated}{Total\ rations\ fed} \times 100$		
kg (distribution data)	Antimicrobials (kg) distributed by CAHI member companies for use in production and comparnion animal in Canada	N/A
$Kilograms\ distributed\ in\ production\ animals\ +\ companion\ animals$		
Population correction unit (PCU)	Total population multiplied by the standard weight of animals at time of treatment	N/A
$Total\ population\ \times std.\ weight\ of\ animals\ in\ kg\ at\ time\ of\ treatment$		
mg/population correction unit (mg/PCU), distribution data	Total quantity of antimicrobials distributed for sale by CAHI member companies (mg)	Population correction unit or biomass: total population, adjusted by the standard animal weights (kg) at treatment (see Chapter 5: Design and methods)
$mg/_{PCU} = \frac{Antimicrobials\ distributed\ (mg)}{PCU\ (kg)}$		
mg/population correction unit (mg/PCU), farm data	Total quantity of antimicrobials consumed by the surveyed animals for one grow-out period in mg	Population correction unit or biomass: total population minus half of the mortalities, adjusted by the standard weight of broiler (1 kg), pig (65 kg) or turkey (6.5 kg)
$mg/_{PCU} = \frac{Feed\ (mg) + water\ (mg) + injection\ (mg)}{PCU\ (total\ animals\ \times std.\ weight\ in\ kg)}$		
nDDDvetCA/1,000 animal-days at risk	Total quantity of antimicrobials consumed by the surveyed animals in mg adjusted for defined daily dose in animals using Canadian standard (mg/DDDvetCA$_{mg/kg/day}$)[a]	Total number of animals minus half of the mortalities multiplied by the weight of the animal and the average days at risk[b]
$nDDDvetCA/_{1{,}000\ animal\ days\ at\ risk} = \left(\frac{Total\ milligrams/_{DDDvetCA_{mg/kg/day}}}{Total\ animals \times std.\ weight\ in\ kg \times average\ days\ at\ risk}\right) \times 1{,}000$		
nDDDvetCA/population correction unit	Total quantity of antimicrobials consumed by the surveyed flock/herd in mg adjusted for defined daily dose in animals using Canadian standard (mg/DDDvetCA$_{mg/kg/day}$)[a]	Population correction unit or biomass: total population minus half of the mortalities, adjusted by the standard weight of broiler chicken (1 kg), grower-finisher pig (65 kg) or turkey (6.5 kg)
$nDDDvetCA/_{PCU} = \frac{Total\ milligrams/DDDvetCA_{mg/kg/day}}{(Total\ animals \times std.\ weight\ in\ kg)}$		

CAHI = Canadian Animal Health Institute.

N/A = not applicable.

For detailed and step-by-step calculations, please refer to Chapter 5: Design and methods.

[a] DDDvetCA standard is in mg/kg per day; please refer to the species-specific standards in Table A. 1 and Table A. 2.

[b] Average days at risk is year-specific (e.g., broiler chickens = 34 days, grower-finisher pigs = 114 days, turkeys = 90 days).

Canadian Animal Health Institute's background information

What is new

Data on ionophores and chemical coccidiostats will now be presented in a section separate from the other antimicrobials, to reduce confusion as to whether these drug classes are included or not in the figures or tables.

What the Canadian Animal Health Institute data include

The Canadian Animal Health Institute (CAHI) is the trade association representing the companies that develop, manufacture and distribute drugs for administration to animals in Canada. The association estimates that its members' sales represent about 95% of all sales of licensed animal health products[44]. Data on active antimicrobial ingredients distributed for sale by CAHI member companies were aggregated and voluntarily provided to CIPARS.

The CAHI data include all animal species, including those not covered by CIPARS farm-level surveillance. Distribution data should always be considered with other sources of information (such as farm-level surveillance and antimicrobial resistance findings) for any decision-making.

What the Canadian Animal Health Institute data do not include

The CAHI data do not include antimicrobials imported under the personal-use provision of the federal Food and Drugs Act Regulations (own use import = OUI), nor do they include imported active pharmaceutical ingredients (API), which are drugs in non-dosage form subsequently compounded by a licensed pharmacist or veterinarian. Health Canada's Veterinary Drugs Directorate has pending regulations regarding these importation processes[45]. These regulations include the requirement for Health Canada to collect information on quantities of antimicrobials sold by manufacturers, importers and persons who compound antimicrobials. These data would be stratified by animal species.

Antimicrobials manufactured for export are excluded from the CAHI data.

The CAHI data do not include prescriptions filled at community pharmacies for antimicrobials to be used in companion or production animals (products labelled for use in humans).

Points of note regarding evaluation of trends

At the time of writing, some of the CAHI member companies re-stated their 2015 data. Hence the data included in this report differ slightly from the data presented in the CIPARS 2015 Annual Report.

In 2016, a new company participated in the data collection by CAHI; though the contribution to the overall tonnage of antimicrobials was minor (personal communication Jean Szkotnicki; president of CAHI).

[44] Canadian Animal Health Institute: About Us. Available at: http://cahi-icsa.ca/about/. Accessed October 2017.

[45] Government of Canada. Canada Gazette. Regulations Amending the Food and Drug Regulations (Veterinary Drug: Antimicrobial Resistance). Vol. 150, No. 27: July 2, 2016. Available at: http://www.gazette.gc.ca/rp-pr/p1/2016/2016-07-02/html/reg2-eng.php. Accessed July 2016.

Quantities of antimicrobials distributed for sale for use in animals

Key findings

In 2016, approximately 1.0 million kg of medically important antimicrobials were distributed for sale for use in animals by CAHI member companies. The reported quantities of antimicrobials do not include antimicrobials imported for "own use" or as active pharmaceutical ingredients intended for further compounding.

For the medically important antimicrobials, over time there was approximately[46] a 14% decline relative to the 2007 total and a 17% decline relative to the 2015 total (Table 3. 2). In comparison to 2015, the antimicrobial classes with the greatest relative decreases in kg were the fluoroquinolones (56%); lincosamides (27%), and the tetracyclines (22%). Only the aminoglycosides had an increase (9% relative increase).

Similar to other years, the predominant classes of antimicrobials distributed for sale in 2016 were the tetracyclines, β-lactams (penicillins), "other antimicrobials"[47], macrolides, and trimethoprim-sulfonamides (based on kg of active ingredient; Table 3. 2 and Figure 3. 1).

There were provincial differences between the quantities of antimicrobials distributed for sale (Table 3. 3, Table 3. 4, and Figure 3. 2) and differences within provinces in the quantities distributed between years. The provinces with the greatest declines since 2015 (as relative percentages of their 2015 kg total) were New Brunswick, Manitoba, Nova Scotia, Newfoundland and Labrador, Saskatchewan, and Québec (decrease of greater than 15% of total kg each). The only province with an increase in total kg active ingredient distributed for sale was Prince Edward Island (20% increase in kg).These differences could be related to different numbers and types of animals in each province, differences in disease pressure, or differences in antimicrobial use or other management practices. The quantities reported per province reflect the quantities distributed to veterinary clinics, feed mills, and over-the-counter outlets by CAHI member companies. There may be subsequent re-distribution of antimicrobials across provincial borders after this point.

In 2016, the quantity of antimicrobials distributed for use in companion animals represented 1% of the total antimicrobials distributed for sale. Antimicrobials distributed for sale for use in companion animal were mostly cephalosporins, β-lactams (penicillins), and trimethoprim and sulfonamides (Table 3. 4 and Figure 3. 3). For production animals, the antimicrobials distributed for sale were mostly tetracyclines, β-lactams (penicillins), and "other antimicrobials"[48] (Table 3. 4 and Figure 3. 4).

[46] CAHI member companies occasionally restate their annual data which can impact the evaluation of trends over time. Every effort is made to ensure comparisons are made with the most up-to-date data available.

[47] "Other antimicrobials" for 2016 included: avilamycin, bacitracins, bambermycin, chloramphenicol, chlorhexidine gluconate, florfenicol, fusidic acid, nitarsone, nitrofurantoin, nitrofurazone, novobiocin, polymixin, tiamulin, and virginiamycin.

[48] "Other antimicrobials" for 2016 included: avilamycin, bacitracins, bambermycin, chloramphenicol, chlorhexidine gluconate, florfenicol, fusidic acid, nitarsone, nitrofurantoin, nitrofurazone, novobiocin, polymixin, tiamulin, and virginiamycin.

Overall, antimicrobials are predominantly distributed for use in feed (76% of total kg) (Figure 3. 5). The predominant classes of antimicrobials vary considerably across the different routes of administration (Figure 3. 5 and Figure 3. 6).

In terms of the Canadian animal population, CIPARS periodically reviews historical animal population numbers and revises them when new data become available. Also, CIPARS changed the Canadian average weight for exported feeder pigs, based on input from an industry expert, and applied this change in weight for this one production phase to all the historical data.

The animal biomass (otherwise known as the population correction unit [PCU]) in Canada has decreased over time from the highest point in 2007. Since 2007, there has been a 15% decline in the PCU and a 1% increase since 2015 using Canadian standard weights; a 14% decline and 1% increase, respectively using European standard weights (Figure 3. 7). Comparing the 2016 animal biomass to 2007 (Canadian standard weights), the respective declines in the PCU were as follows: cattle 23%, swine 8%, rabbits 6%, and sheep and goats 2%. Poultry increased by 2% and fish (finfish and shellfish) increased by 32%. The results were similar using the European standard weights. Recent live horse data were not available at the time of writing. The 2016 animal populations and weights used in the calculation can be found in Table 3. 5 (abbreviated) and Table 3. 6 (detailed).

For production animals, the total quantity of antimicrobials distributed for sale per kg of animal (mg/PCU) was approximately 150 using European standard weights and 130 using Canadian standard weights. This represents a decrease of 2% since 2007 and a decrease of 18% since 2015 using European standard weights and a decrease of less than 1% and 17% respectively, using Canadian standard weights (Figure 3. 8). The mg/PCU for companion animals was 89.

For international comparison, the European Surveillance of Veterinary Antimicrobial Consumption (ESVAC), at the time of writing, had data available for 30 European countries for 2015[49]. Comparing the most recent data (Canada 2016, ESVAC 2015), Canada had the 5th highest consumption of antimicrobials on a per kg animal basis (Figure 3. 9). It is critical to recognize that Canada's position would be further to the left on the figure (higher mg drug/PCU) if we could account for the currently unrecorded imports of antimicrobials which fall under own-use importation and imports of active pharmaceutical ingredients intended for further compounding. The 2016 Canadian consumption per kg animal was higher than the reported average for 2015 for the 30 European countries[50]. It is important to note that the Canadian denominator data included the numbers of live beef cows, which are not included as a separate category in the European data. It is important to recognize with this international comparison, that the structure and detail in the data for animal production classes available in the European datasets differ from the Canadian datasets (see Chapter 5: Design and methods); hence this figure should be interpreted with caution.

[49]European Medicines Agency, European Surveillance of Veterinary Antimicrobial Consumption, 2017. "Sales of veterinary antimicrobial agents in 30 European countries in 2015". (EMA/184855/2017). Available at: http://www.ema.europa.eu/docs/en_GB/document_library/Report/2017/10/WC500236750.pdf. Accessed October 2017.

[50] European Medicines Agency, European Surveillance of Veterinary Antimicrobial Consumption, 2017. "Sales of veterinary antimicrobial agents in 30 European countries in 2015". (EMA/184855/2017). Available at: http://www.ema.europa.eu/docs/en_GB/document_library/Report/2017/10/WC500236750.pdf. Accessed October 2017.

In terms of ionophores and chemical coccidiostats, 0.6 million kg of these products were distributed in 2016 (Table 3. 7). Since 2015, there has been a 4% increase in the quantity of ionophores distributed for sale and a 17% decrease in the quantity of chemical coccidiostats distributed for sale. These products represented 36% of the total antimicrobials distributed for sale for use in animals in 2016 (Figure 3. 10).

National-level antimicrobial distribution data

Table 3. 2 Quantity of antimicrobials (kg) distributed in Canada for sale for use in animals, 2007 to 2016

Antimicrobial class aggregation	Quantity of active ingredient (kg)										Change (%) from 2007 to 2016	Change (%) from 2015 to 2016
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016		
Aminoglycosides	4,302										NA	NA
		5,817	4,652	3,961							NA	NA
					12,242	10,372	10,785				NA	NA
								13,276	13,718	14,952	NA	9%
Amphenicols	NA	3,242	4,001	4,391							NA	NA
β-Lactams (penicillins)	52,594										NA	NA
		109,153	118,109	201,934							NA	NA
					147,853						NA	NA
						136,611					NA	NA
							134,838	139,278	139,565	133,722	NA	-4%
Cephalosporins	850	NA	NA	NA							NA	NA
					6,716	6,388	2,403	6,812	6,795	6,766	NA	0%
Fluoroquinolones	443	411	377	381	519	406	469	782	860	378	-15%	-56%
Lincosamides	55,872	41,222	44,137	46,373	43,256	51,027	54,784	60,006	65,646	48,083	-14%	-27%
Macrolides and pleuromutilins	118,725										NA	NA
Macrolides, pleuromutilins, and bacitracins	NA	210,869	204,169	170,154							NA	NA
Macrolides	NA	NA	NA	NA	108,858	98,622	93,870	112,340	114,186	97,453	NA	-15%
Other antimicrobials	146,880										NA	NA
		32,706	21,339	26,757							NA	NA
					130,899						NA	NA
						129,614					NA	NA
							125,511				NA	NA
								125,178	128,144	121,752	NA	-5%
Tetracyclines	753,168	680,601	686,832	535,142	600,918	635,435	635,675	599,540	659,784	513,890	-32%	-22%
	38,961	59,166	57,596	48,221	70,454	58,716					NA	NA
Trimethoprim and sulfonamides							63,367	69,255	72,564	65,318	NA	-10%
Total	**1,171,796**	**1,143,187**	**1,141,213**	**1,037,313**	**1,121,715**	**1,127,191**	**1,121,702**	**1,126,467**	**1,201,263**	**1,002,313**	**-14%**	**-17%**

See corresponding footnotes on next pages.

Table 3. 2 Quantity of antimicrobials (kg) distributed in Canada for sale for use in animals, 2007 to 2016 (continued)

NA = not available or not applicable.

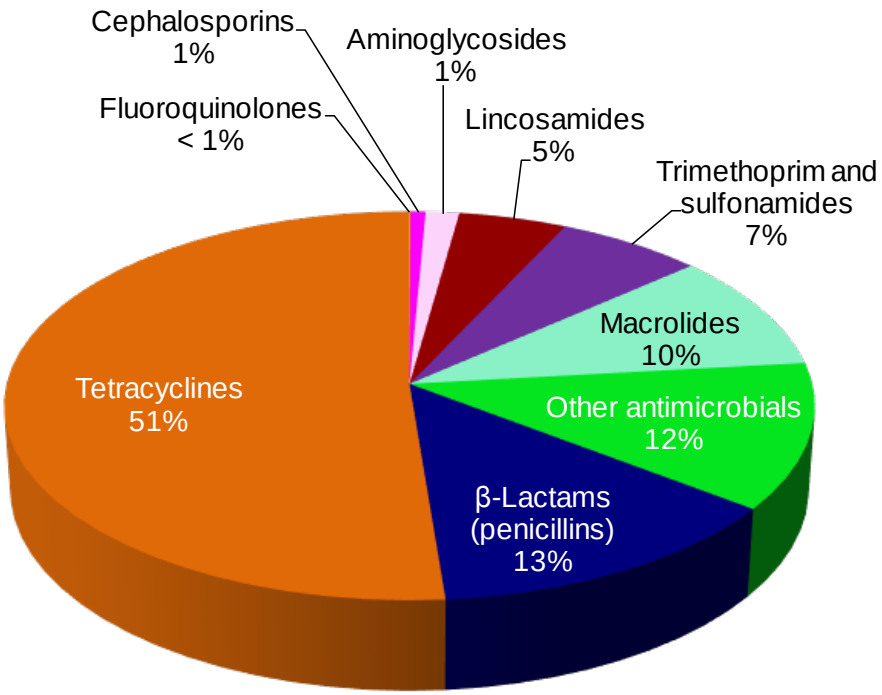
Changes in percentage over time from 2007 to 2016 are relative to the quantities reported in 2007. Changes in percentage over time from 2015 to 2016 are relative to the quantities reported in 2015.

Animal distribution data do not include antimicrobials imported under the “own use” provision or imported as active pharmaceutical ingredients intended for further compounding; hence, are underestimates of total quantities used.

CAHI provides the information according to a “3 company accounting rule” established by CAHI to comply with the European Union and the United States’ anti-competition regulations. CAHI added in some cases a “90% rule” to be sure not to infringe the regulations in the United States. These accounting rules can result in changes to the categorization of specific antimicrobials over time; hence within an antimicrobial category, columns with different colours should not be compared.

“Other antimicrobials” for 2016 included: avilamycin, bacitracins, bambermycin, chloramphenicol, chlorhexidine gluconate, florfenicol, fusidic acid, nitarsone, nitrofurantoin, nitrofurazone, novobiocin, polymixin, tiamulin, and virginiamycin.

Figure 3. 1 Percentages of the quantities (kg of active ingredient) of antimicrobials distributed in Canada for sale for use in animals, 2016



Animal distribution data do not include antimicrobials imported under the "own use" provision or imported as active pharmaceutical ingredients intended for further compounding; hence, are underestimates of total quantities used.

"Other antimicrobials" for 2016 included: avilamycin, bacitracins, bambermycin, chloramphenicol, chlorhexidine gluconate, florfenicol, fusidic acid, nitrofurantoin, nitrofurazone, novobiocin, polymixin, tiamulin, and virginiamycin

Provincial-level antimicrobial distribution data

Table 3. 3 Quantity of antimicrobials (kg of active ingredient) distributed for sale for use in animals by province, 2015 to 2016

Year	Province	Aminoglycosides	β-Lactams (penicillins)	Cephalosporins	Fluoroquinolones	Lincosamides	Macrolides	Other antimicrobials	Tetracyclines	Trimethoprim and sulfonamides	Total
2016	BC	830	9,781	764	44	79	484	9,332	29,409	2,038	52,761
	AB	1,004	14,228	1,117	80	6,938	26,816	20,249	111,940	8,691	191,063
	SK	652	3,301	272	4	2,654	3,144	4,353	22,967	2,879	40,225
	MB	1,021	14,977	397	15	9,204	20,543	9,168	67,034	6,556	128,916
	ON	5,642	58,837	2,460	173	16,233	25,535	40,922	118,317	28,980	297,098
	QC	5,302	28,992	1,374	49	12,918	20,494	35,087	157,487	15,277	276,979
	NS	215	1,431	179	8	34	398	1,625	3,912	266	8,067
	NB	123	1,144	115	2	20	11	123	2,481	446	4,464
	PE	58	734	38	0	2	26	87	328	104	1,378
	NL	106	296	50	1	1	0	807	15	81	1,357
Total		**14,952**	**133,721**	**6,766**	**375**	**48,083**	**97,453**	**121,752**	**513,890**	**65,318**	**1,002,309**
2015	BC	669	11,664	768	127	104	606	10,990	32,584	2,555	60,067
	AB	838	16,825	1,122	222	8,332	30,000	22,054	119,530	11,551	210,475
	SK	842	3,878	272	7	3,123	3,953	5,624	29,058	3,951	50,708
	MB	743	17,612	397	36	19,021	25,823	13,824	92,543	9,661	179,660
	ON	4,412	56,508	2,476	319	19,314	30,294	41,225	153,971	27,530	336,049
	QC	5,841	29,328	1,377	123	15,667	22,941	30,517	221,503	16,246	343,544
	NS	182	1,533	180	20	56	472	2,432	5,691	526	11,092
	NB	108	1,271	115	3	24	88	137	4,666	369	6,780
	PE	50	635	38	1	2	9	90	209	112	1,147
	NL	34	309	50	2	3	1	1,251	28	63	1,740
Total		**13,718**	**139,565**	**6,795**	**860**	**65,646**	**114,186**	**128,144**	**659,784**	**72,564**	**1,201,263**

Province abbreviations are defined in the Appendix.

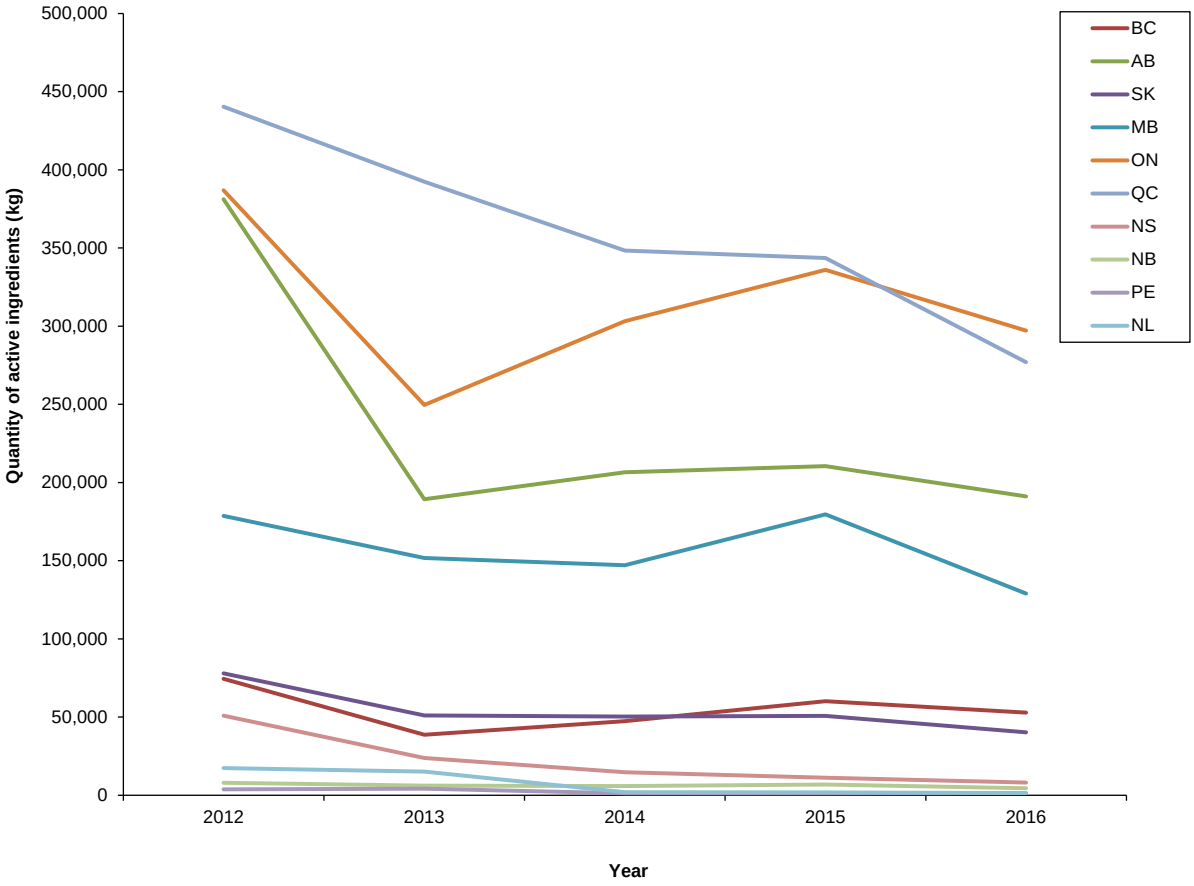
CAHI accounting rules can result in changes in changes of antimicrobial categorizations over time. Please consult Table 3. 1 to determine whether an appropriate comparison across years can be made for that antimicrobial class.

There may be subsequent distribution of antimicrobials across provincial borders after being distributed to the veterinary clinics.

Animal distribution data do not include antimicrobials imported under the “own use” provision or imported as active pharmaceutical ingredients intended for further compounding; hence, are underestimates of total quantities used.

“Other antimicrobials” for 2016 included: avilamycin, bacitracins, bambermycin, chloramphenicol, chlorhexidine gluconate, florfenicol, fusidic acid, nitarsone, nitrofurantoin, nitrofurazone, novobiocin, polymixin, tiamulin, and virginiamycin.

Figure 3. 2 Quantity of antimicrobials (kg of active ingredient) distributed for sale for use in animals by province, 2012 to 2016



This figure does not account for provincial differences in numbers or types of animals.

Province abbreviations are defined in the Appendix.

There may be subsequent distribution of antimicrobials across provincial borders after being distributed to the veterinary clinics.

Animal distribution data do not include antimicrobials imported under the “own use” provision or imported as active pharmaceutical ingredients intended for further compounding; hence, are underestimates of total quantities used.

Distribution by animal type

Table 3. 4 Quantity of antimicrobials (kg of active ingredient) distributed for sale for use in animals by province and animal type, 2016

Animal type / province	Aminoglycosides	β-Lactams (penicillins)	Cephalosporins	Fluoroquinolones	Lincosamides	Macrolides	Other antimicrobials	Tetracyclines	Trimethoprim and sulfonamides	Total
Production animal										
BC	826	9,474	252	30	79	484	9,295	29,409	1,921	51,769
AB	998	13,781	369	54	6,923	26,816	20,168	111,940	8,191	189,241
SK	648	3,198	90	2	2,649	3,144	4,335	22,967	2,714	39,746
MB	1,016	14,507	131	10	9,184	20,543	9,131	67,034	6,180	127,736
ON	5,610	56,991	812	116	16,199	25,535	40,758	118,317	27,313	291,652
QC	5,273	28,082	454	33	12,891	20,494	34,946	157,487	14,398	274,058
NS	214	1,387	59	5	34	398	1,618	3,912	251	7,877
NB	122	1,108	38	1	20	11	123	2,481	420	4,324
PE	57	711	13	0	2	26	86	328	98	1,322
NL	105	286	17	1	1	0	804	15	77	1,305
Total	**14,868**	**129,524**	**2,234**	**253**	**47,981**	**97,453**	**121,265**	**513,890**	**61,562**	**989,030**
Companion animal										
BC	5	307	512	14	0	0	37	0	117	993
AB	6	447	748	26	15	0	81	0	500	1,822
SK	4	104	182	1	6	0	17	0	166	479
MB	6	470	266	5	20	0	37	0	377	1,180
ON	31	1,846	1,648	56	35	0	164	0	1,666	5,446
QC	30	910	920	16	28	0	140	0	878	2,922
NS	1	45	120	3	0	0	6	0	15	190
NB	1	36	77	1	0	0	0	0	26	140
PE	0	23	26	0	0	0	0	0	6	55
NL	1	9	34	0	0	0	3	0	5	52
Total	**83**	**4,196**	**4,532**	**122**	**102**	**0**	**487**	**0**	**3,756**	**13,279**
Total (animal types combined)										
	14,952	**133,721**	**6,766**	**375**	**48,083**	**97,453**	**121,752**	**513,890**	**65,318**	**1,002,309**

Production animals include horses.

Province abbreviations are defined in the Appendix.

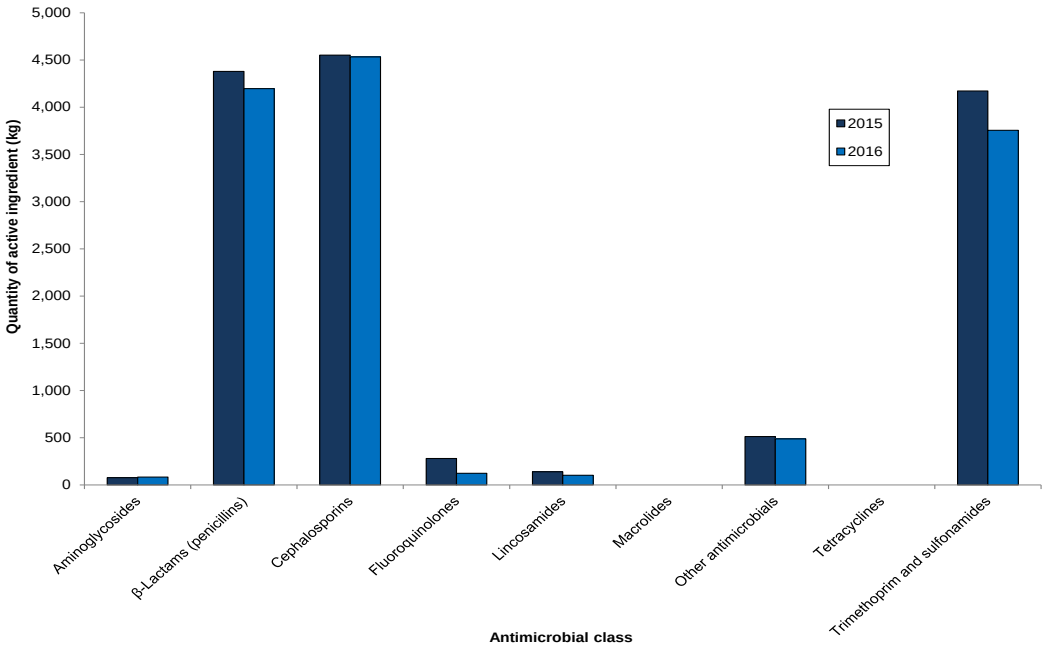
The attribution of antimicrobials sold in each province to the type of animal (companion animals vs. production animals) was based on multiplying a national average percentage of the antimicrobial sold for companion animals/production animals by the total quantities reported for that province by the manufacturers.

Animal distribution data do not include antimicrobials imported under the “own use” provision or imported as active pharmaceutical ingredients intended for further compounding; hence, are underestimates of total quantities used.

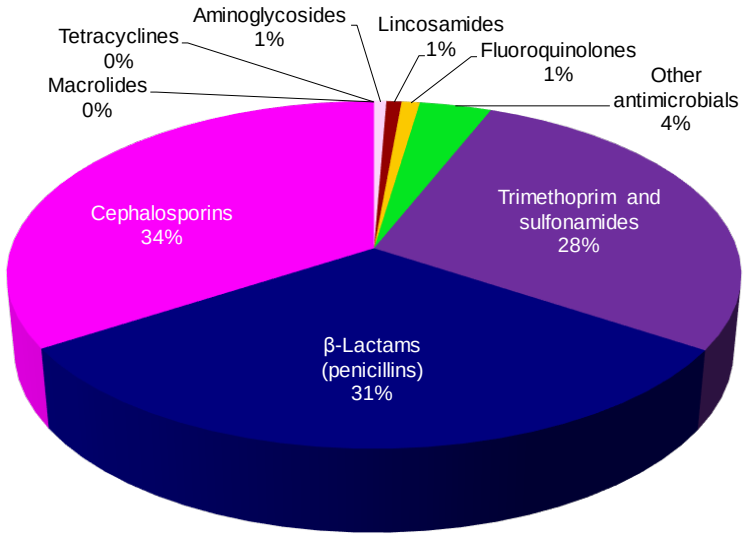
“Other antimicrobials” for 2016 included: avilamycin, bacitracins, bambermycin, chloramphenicol, chlorhexidine gluconate, florfenicol, fusidic acid, nitarsone, nitrofurantoin, nitrofurazone, novobiocin, polymixin, tiamulin, and virginiamycin.

Figure 3. 3 Quantity of antimicrobials (kg of active ingredient) distributed for sale for use in companion animals over time and in 2016

a) Over time



a) 2016



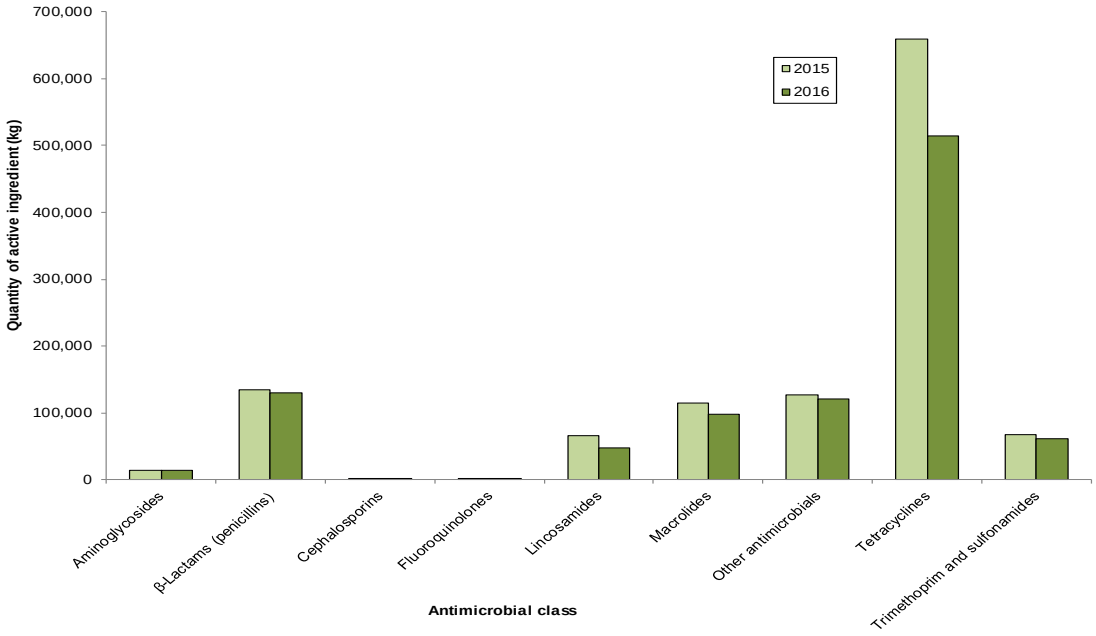
Antimicrobial sales were assigned to animal type according to label claim and in the situation where mixed species was indicated on the label, the manufacturer assigned the kg to either “Companion animal” or “Production animal”.

Animal distribution data do not include antimicrobials imported under the “own use” provision or imported as active pharmaceutical ingredients intended for further compounding; hence, are underestimates of total quantities used.

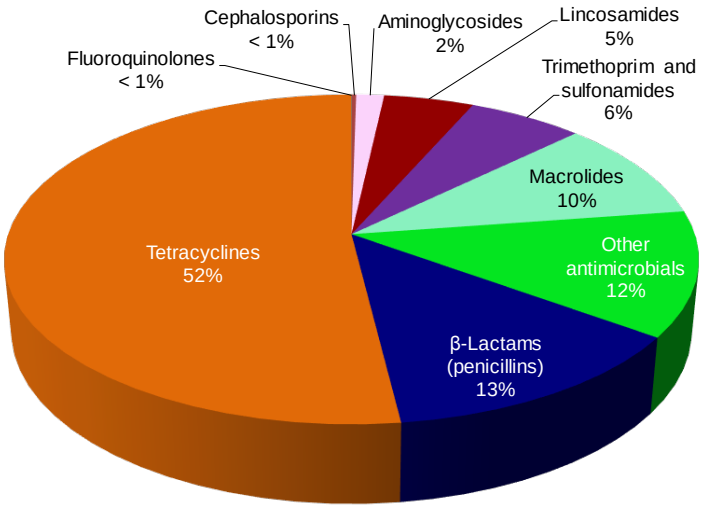
“Other antimicrobials” for 2016 included: avilamycin, bacitracins, bambermycin, chloramphenicol, chlorhexidine gluconate, florfenicol, fusidic acid, nitarsone, nitrofurantoin, nitrofurazone, novobiocin, polymixin, tiamulin, and virginiamycin.

Figure 3. 4 Quantity of antimicrobials (kg of active ingredient) distributed for sale for use in production animals over time, 2016

a) Over time



b) 2016



Note the differences in scale of the vertical axes between the companion animal figure (Figure 3. 3a) and the production animal figure. Production animals include horses.

Antimicrobial sales were assigned to animal type according to label claim and in the situation where mixed species was indicated on the label, the manufacturer assigned the kg to either “Companion animal” or “Production animal”.

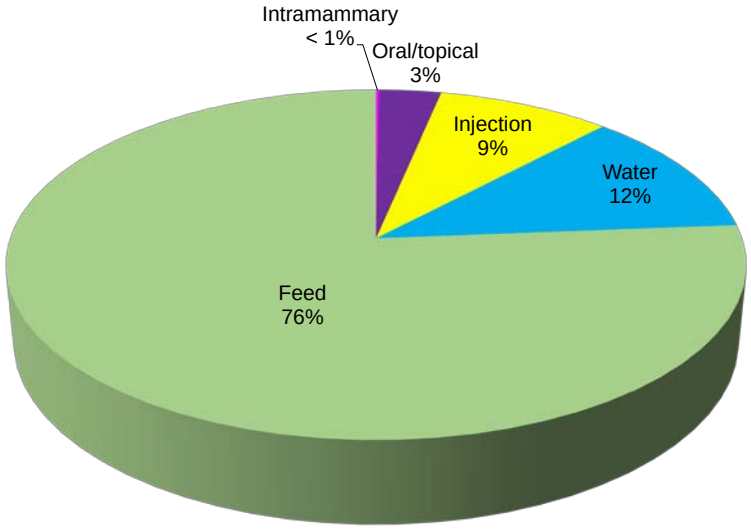
Animal distribution data do not include antimicrobials imported under the “own use” provision or imported as active pharmaceutical ingredients intended for further compounding; hence, are underestimates of total quantities used.

“Other antimicrobials” for 2016 included: avilamycin, bacitracins, bambermycin, chloramphenicol, chlorhexidine gluconate, florfenicol, fusidic acid, nitarsone, nitrofurantoin, nitrofurazone, novobiocin, polymixin, tiamulin, and virginiamycin.

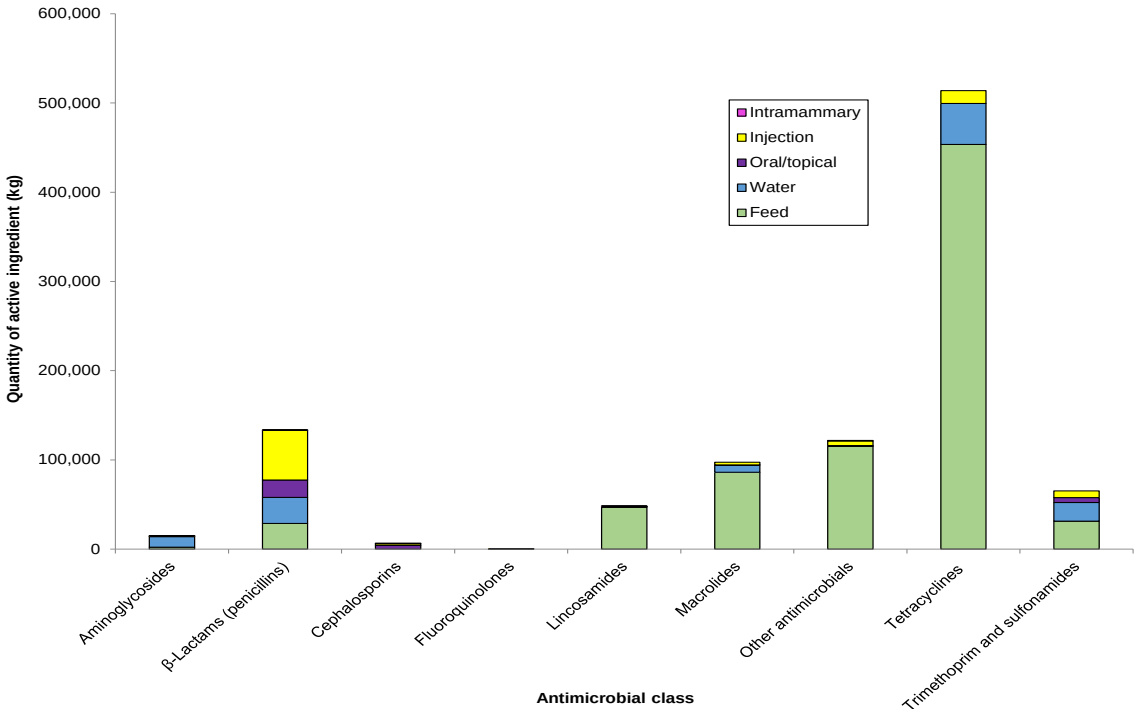
Distribution by route of administration

Figure 3. 5 Quantity of antimicrobials (% of total kg and kg of active ingredient) distributed for sale for use in animals, by route of administration and antimicrobial class, 2016

a) Route of administration



b) Antimicrobial class

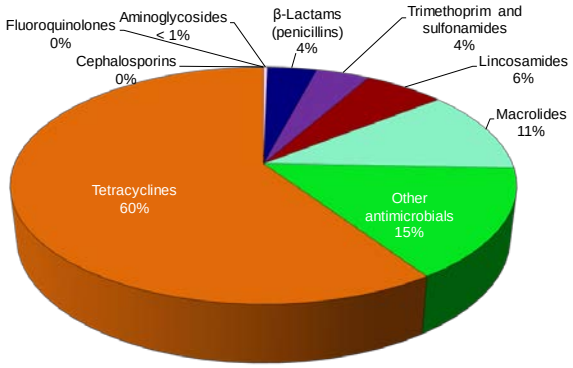


Animal distribution data do not include antimicrobials imported under the "own use" provision or imported as active pharmaceutical ingredients intended for further compounding; hence, are underestimates of total quantities used.

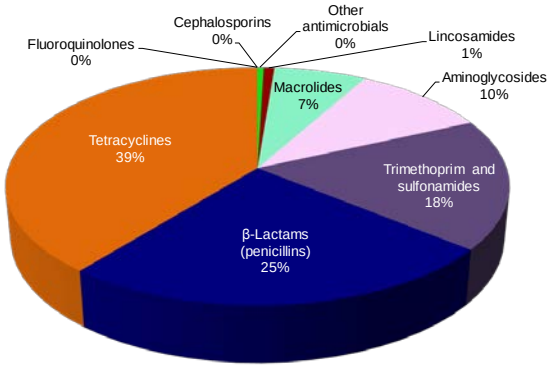
"Other antimicrobials" for 2016 included: avilamycin, bacitracins, bambermycin, chloramphenicol, chlorhexidine gluconate, florfenicol, fusidic acid, nitarsone, nitrofurantoin, nitrofurazone, novobiocin, polymixin, tiamulin, and virginiamycin.

Figure 3. 6 Quantity of antimicrobials (% of total kg) distributed for sale for use in animals, by route of administration (feed, water, injection, oral or topical, and intra-mammary), 2016

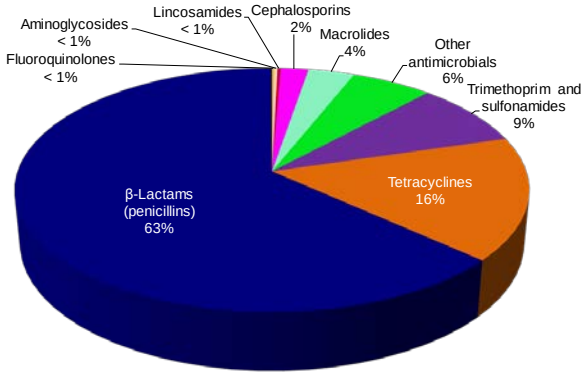
a) Feed



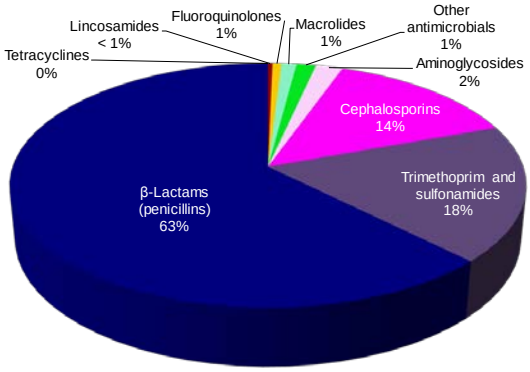
b) Water



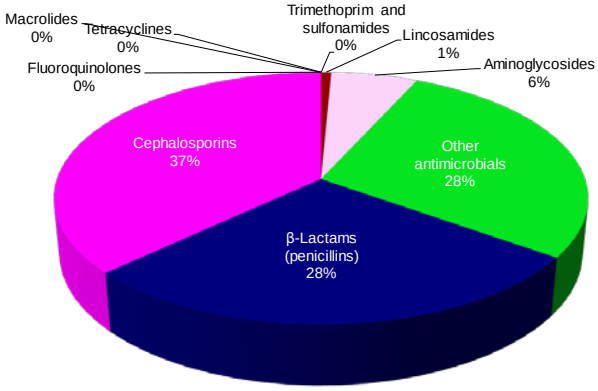
c) Injection



d) Oral or topical



e) Intra-mammary



Animal distribution data do not include antimicrobials imported under the "own use" provision or imported as active pharmaceutical ingredients intended for further compounding; hence, are underestimates of total quantities used.

"Other antimicrobials" for 2016 included: avilamycin, bacitracins, bambermycin, chloramphenicol, chlorhexidine gluconate, florfenicol, fusidic acid, nitarsone, nitrofurantoin, nitrofurazone, novobiocin, polymixin, tiamulin, and virginiamycin

Antimicrobial distribution data and animal biomass in Canada: the population correction unit (PCU) over time

Table 3. 5 Canadian animal population numbers and population correction unit (PCU), 2016

Animal species	Number of animals and/or kg fish	PCU_{ESVAC} (1,000 tonnes)[a]	PCU_{CAN} (1,000 tonnes)[b]
Cattle	8,484,510	3,310	4,227
Swine	28,086,031	1,859	1,757
Poultry	650,740,838	770	883
Sheep and goats	1,318,914	55	55
Horses	963,500	385	482
Fish	200,565,000	201	201
Rabbit	621,431	1	1
Total production animals		**6,581**	**7,606**
Cats	8,800,000	35	35
Dogs	7,600,000	114	114
Total companion animals		**149**	**149**

For more detailed information on data sources and specific information on production stages, imports, exports, please see Table 3. 6.

The data used for live horses was from 2010 and fish from 2015; more recent data were unavailable at the time of writing of this report.

ESVAC = European Surveillance of Veterinary Antimicrobial Consumption

CAN = Canadian

Acknowledging the underlying sources of data structure the information differently, the PCU denominator was harmonized to the greatest extent possible with ESVAC[51]. ESVAC denominator does not include beef cows, whereas in Canada beef cows are a significant population and are included in both figures.

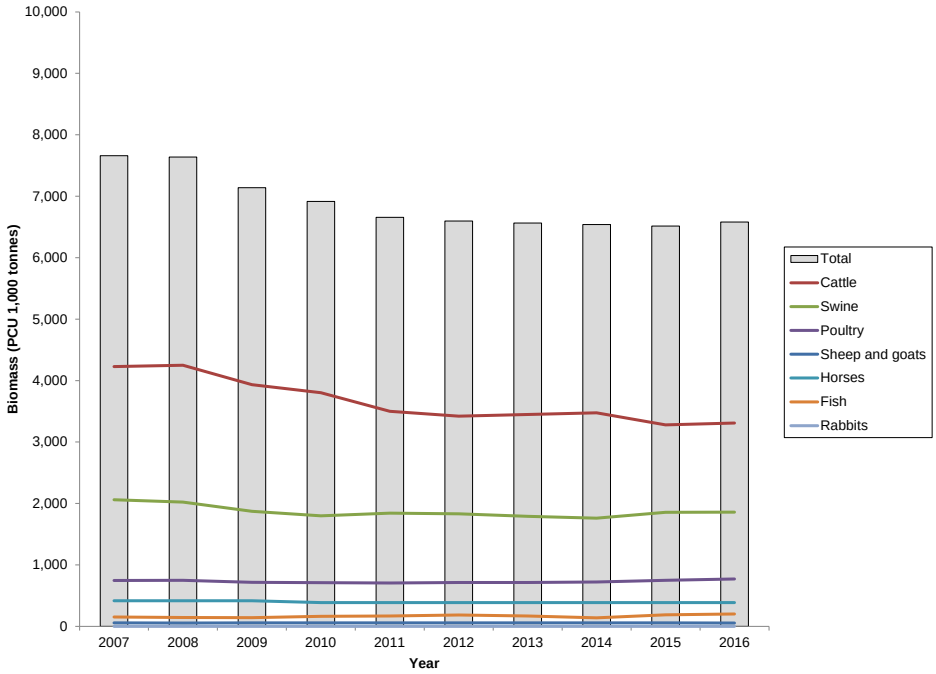
[a] PCU_{ESVAC} is based on ESVAC weights.

[b] PCU_{CAN} is based on Canadian weights.

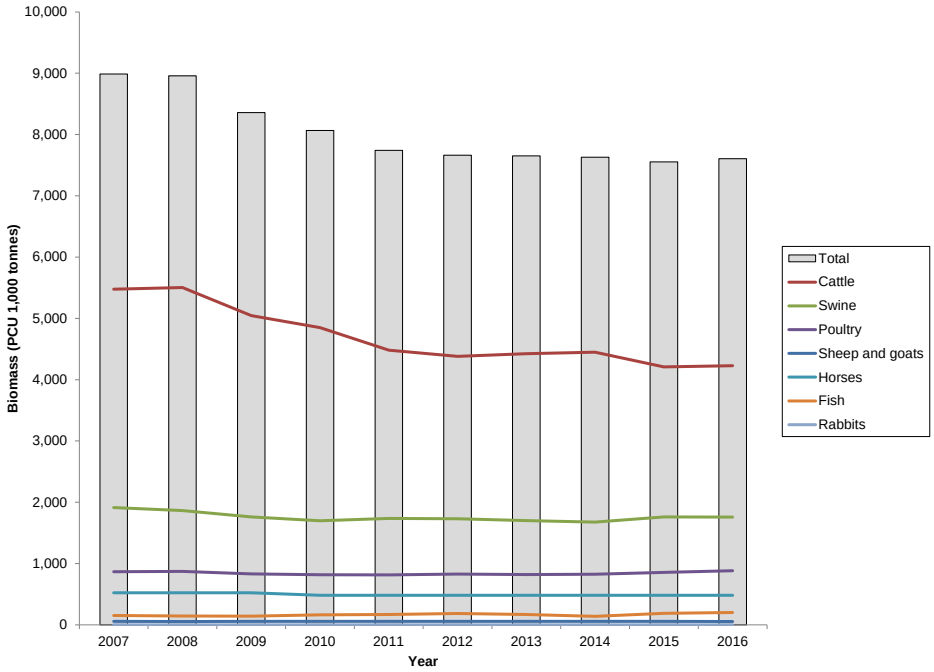
[51] European Medicines Agency, European Surveillance of Veterinary Antimicrobial Consumption. ESVAC Population correction unit template. Available at: http://www.ema.europa.eu/ema/index.jsp?curl=pages/regulation/document_listing/document_listing_000302.jsp. Accessed October 2017.

Figure 3. 7 Biomass as measured by the population correction unit (PCU in 1,000 tonnes) over time; using European Surveillance of Veterinary Antimicrobial Consumption production classes, European weights and Canadian standard weights, 2007 to 2016

a) European weights



b) Canadian weights



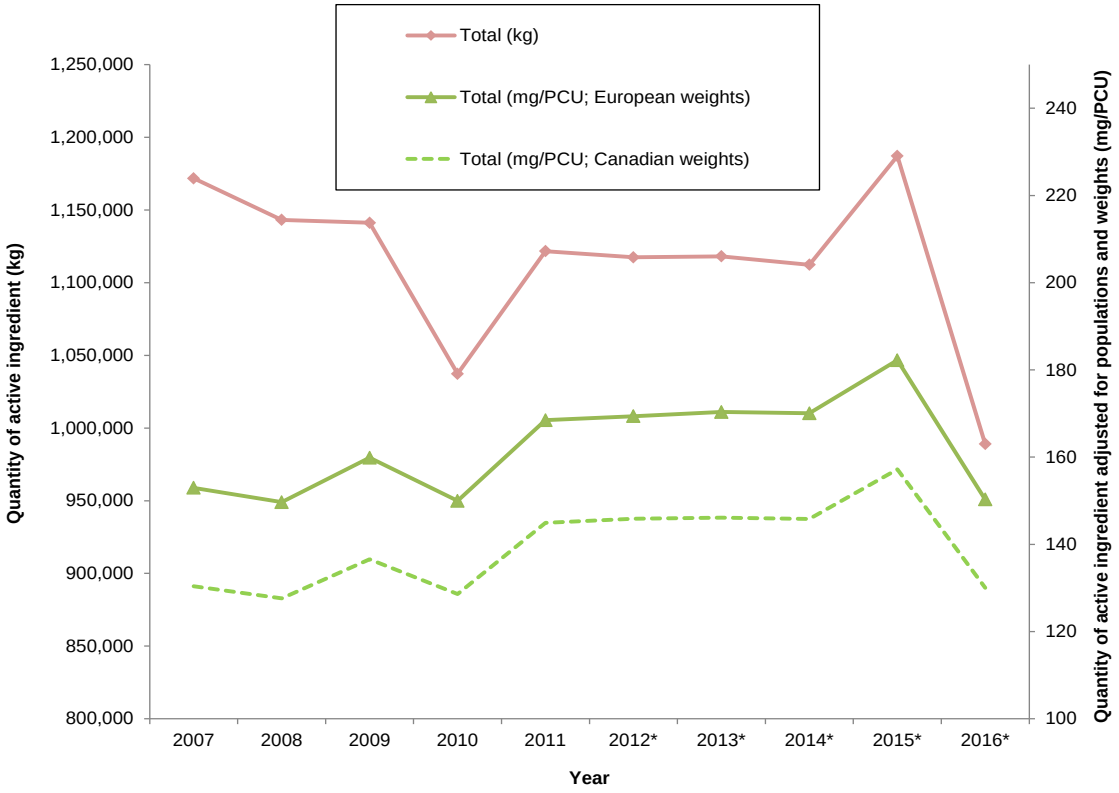
See corresponding footnotes on next page.

Figure 3. 7 Biomass as measured by the population correction unit (PCU in 1,000 tonnes) over time; using European Surveillance of Veterinary Antimicrobial Consumption production classes, European weights and Canadian standard weights, 2007 to 2016 (continued)

The data used for live horses was from 2010; more recent data were unavailable at the time of writing of this report.

Acknowledging the underlying sources of data structure the information differently, the PCU denominator was harmonized to the greatest extent possible with the European Surveillance of Veterinary Antimicrobial Consumption (ESVAC)52. ESVAC denominator does not include beef cows, whereas in Canada beef cows are a significant population and are included in both figures.

Figure 3. 8 Antimicrobials distributed for sale for use in animals over time (kg of active ingredient and mg/PCU), 2007 to 2016



PCU = population correction unit.

The data used for live horses was from 2010 and fish was from 2015; more recent data were unavailable at the time of writing of this report.

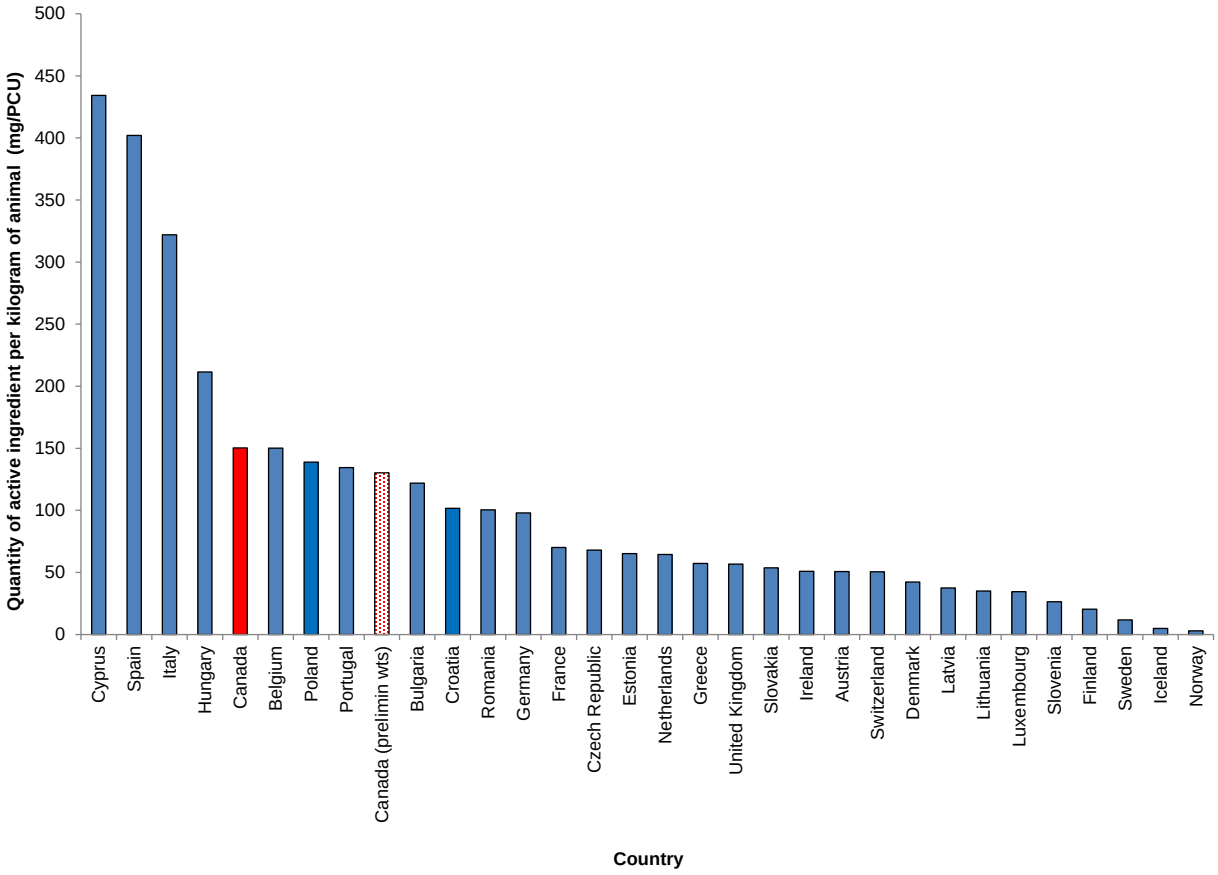
Animal distribution data do not include antimicrobials imported under the "own use" provision or imported as active pharmaceutical ingredients intended for further compounding; hence, are underestimates of total quantities used.

* Indicates data excluded antimicrobials sold for use in companion animals.

[52] European Medicines Agency, European Surveillance of Veterinary Antimicrobial Consumption. ESVAC Population correction unit template. Available at: http://www.ema.europa.eu/ema/index.jsp?curl=pages/regulation/document_listing/document_listing_000302.jsp. Accessed October 2016.

International data

Figure 3. 9 Sales of antimicrobials (adjusted by populations and weights) for Canada (2016) and countries participating in the European Surveillance of Veterinary Antimicrobial Consumption (ESVAC) network (2015)



PCU = population correction unit.

The Canadian data used for live horses was from 2010 and fish from 2015; more recent data were unavailable at the time of writing of this report.

Animal distribution data do not include antimicrobials imported under the "own use" provision or imported as active pharmaceutical ingredients intended for further compounding; hence, are underestimates of total quantities used.

The PCU denominator was harmonized to the greatest extent possible with the European Surveillance of Veterinary Antimicrobial Consumption (ESVAC)[53]. ESVAC denominator does not include beef cows, whereas in Canada beef cows are a significant population and are included. The ESVAC approach excludes companion animal data from the numerator.

Data from all countries shown are using the same average weights at treatment. However, Canadian average weights in many production classes are heavier than European average weights. As per stakeholder request, based on preliminary analysis, the lighter red column for Canada indicates where Canada would rank if Canadian average weights at treatment were used in the calculations.

[53] European Medicines Agency, European Surveillance of Veterinary Antimicrobial Consumption, 2016. "Sales of veterinary antimicrobial agents in 29 European countries in 2014". (EMA/61769/2016). Available at: http://www.ema.europa.eu/docs/en_GB/document_library/Report/2016/10/WC500214217.pdf. Accessed October 2017.

Detailed denominator data

Table 3. 6 Detailed information on population numbers, 2016

Animal species	Animal class/production class	Production stage	Number of animals	ESVAC average weight at treatment or standard weight for import/export (kg)[a]	PCU_{ESVAC} (1,000 tonnes)	Canadian average weight at treatment or standard weight for import/export (kg)[a]	PCU_{CAN} (1,000 tonnes)
			n	w_1	$(n*w_1)/(1,000*1,000)$ (imports subtracted)	w_2	$(n*w_2)/(1,000*1,000)$ (imports subtracted)
Cattle							
	Cattle	Slaughter[b]	2,802,568				
	Cows	Slaughter	414,552	425	176	600	249
	Heifers	Slaughter	822,703	200	165	200	165
	Steers and bulls	Slaughter	1,565,312	425	665	425	665
	Calves	Slaughter[b]	236,858	140	33	249	59
	Slaughter cattle and calves	Export for slaughter to the US[c]	574,531	425	244	425	244
	Calves	Live cattle and calf international import for feeding or slaughter[d]	-26,492	140	-4	249	-7
	Feeder cattle and calves	Export for feeding to US[c]	179,045	140	25	249	45
	Beef cows	On farm[e]	3,772,900	425	1,603	600	2,264
	Dairy cows	On farm[e]	945,100	425	402	575	543
	Total		8,484,510		3,310		4,227
Swine							
	Finishers	Slaughter[f]	21,261,873	65	1,382	65	1,382
	All swine	International import[g]	-2,500	65	0	65	0
	Swine	Export for feeding to US[c]	4,621,477	25	116	3[s]	14
	Swine	Export for slaughter to the US[c]	957,281	65	62	65	62
	Sows and gilts (6 months and over)	On farm[h]	1,247,900	240	299	240	299
	Total		28,086,031		1,859		1,757
Poultry							
	Chickens (categories < 1.4 kg, 1.4 and < 2.7 kg, >2.7 kg)	Slaughter[i]	681,913,737	1	682	1.2	818
	Turkey (categories < 6.2 kg, > 6.2 but not > 8.5 kg, > 8.5 kg but not > 10.8 kg, > 10.8 kg but not > 13.3 kg, > 13.3 kg, mature turkeys)	Slaughter[i]	21,735,443	6.5	141	6.5	141
	Poultry (< 185 g)	Live poutry for import[j]	-34,951,648	1	-35	0.2	-7
	Poultry (> 185 g)	Live poutry for import[j]	-37,607,376	1	-38	2	-75
	Poultry (< 185 g)	Export[j]	18,506,325	1	19	0.2	4
	Poultry (> 185 g)	Export[j]	1,144,357	1	1	2	2
	Total		650,740,838		770		883
Sheep and goats							
	Sheep and lamb	Slaughter[k]	721,000	20	14	20	14
	Goats	Slaughter[l]	57,118	20	1	20	1
	Sheep and lamb	International import[k]	0	20	0	20	0
	Sheep and lamb	International export[c]	13,996	20	0	20	0
	Ewes	On farm[m]	526,800	75	40	75	40
	Total		1,318,914		55		55
Horses	Horses	Living[n]	963,500	400	385	500	482
Fish							
	Finfish	Production (kg)[o]	160,054,000	N/A	160	N/A	160
	Shellfish	Production (kg)[o]	40,511,000	N/A	41	N/A	41
	Total		200,565,000		201		201
Rabbits		Slaughter[p]	621,431	1.4	1	1.4	1
Total PCU production animals					**6,581**		**7,606**
Cats	N/A	N/A[q, r]	8,800,000	4	35.2	4	35
Dogs	N/A	N/A[q, r]	7,600,000	15	114	15	114
Total PCU companion animals					**149**		**149**

See corresponding footnotes on next pages.

Table 3. 6 Detailed information on population numbers, 2016 (continued)

For horses, data on number of horses on farm were only reported for 2006 and 2010.

N/A = Not applicable.

[a] As per European Surveillance of Veterinary Antimicrobial Consumption (ESVAC), unless otherwise specified. ESVAC does not include beef cows. Beef cows are included here because they are a significant animal population in Canada.

[b] Data from federal and provincial slaughter plants. Available at: http://aimis-simia.agr.gc.ca/rp/index-eng.cfm?action=rR&pdctc=&r=105&menupos=1.02.06 and http://aimis-simia.agr.gc.ca/rp/index-eng.cfm?action=rR&pdctc=&r=111&menupos=1.02.06. Accessed August 2017. These data were parsed into various animal categories (cows, heifers, steers and bulls) according to the % of these animals slaughtered at the federal level. Available at: http://aimis-simia.agr.gc.ca/rp/index-eng.cfm?action=pR&pdctc=&r=109. Accessed August 2016. This makes the assumption that the percentages of each animal category slaughtered at the provincial level are the same as at the federal level.

[c] Cattle, swine, and sheep export numbers for feeding and slaughter. Sheep export numbers for feeding and slaughter were combined as they have the same standard weight in ESVAC. Available at: http://aimis-simia.agr.gc.ca/rp/index-eng.cfm?action=rR&pdctc=&r=191. Accessed October 2017.

[d] Supply comparison by species between Canada and the United States. Table 3. Available at: http://www.agr.gc.ca/eng/industry-markets-and-trade/statistics-and-market-information/by-product-sector/red-meat-and-livestock/red-meat-and-livestock-market-information/supply-sheets-by-species/supply-comparision-by-species-between-canada-and-the-united-states/?id=1415860000063. Accessed October 2017.

[e] Table 003-0032. On all cattle operations. Data for January 1st. Available at: http://www5.statcan.gc.ca/cansim/a26?lang=eng&retrLang=eng&id=0030032&&pattern=&stByVal=1&p1=1&p2=-1&tabMode=dataTable&csid=. Accessed October 2017.

[f] Agriculture and Agri-Food Canada (Report A005C). Available at: http://aimis-simia.agr.gc.ca/rp/index-eng.cfm?menupos=1.02.06&pdctc=&action=pR&LANG=EN&r=93. Accessed October 2017.

[g] Added for Periods I and II. Statistics Canada (CANSIM Table 003-0102). Available at: http://www5.statcan.gc.ca/cansim/a26?id=0030102&pattern=&p2=-1&tabMode=dataTable&p1=1&stByVal=1&+lang=eng&paSer=&csid=&retrLang=eng&lang=eng. Accessed October 2017.

[h] Number of animals recorded for Period II for 2016. Statistics Canada (CANSIM 003-0100). Available at: www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/prim51a-eng.htm. Accessed October 2017.

[i] Live weight. For turkeys, mature birds were in a separate designated category and were included. Agriculture and Agri-Food Canada (Poultry Slaughter - Report 001). Available at: http://aimis-simia.agr.gc.ca/rp/index-eng.cfm?action=pR&r=1&pdctc=. Accessed October 2017.

[j] Included all poultry - total live birds. Agriculture and Agri-Food Canada (Poultry and Egg Trade Balance Report). Available at: http://www.agr.gc.ca/eng/industry-markets-and-trade/statistics-and-market-information/by-product-sector/poultry-and-eggs/poultry-and-egg-market-information-canadian-industry/imports-and-exports/statistics-canada-poultry-and-egg-trade-reports/2014-poultry-and-egg-trade-balance-reports/?id=1426000524082. Accessed October 2017.

[k] Statistics Canada (CANSIM 003-0028). Available at: www5.statcan.gc.ca/cansim/a26?lang=eng&retrLang=eng&id=0030028&tabMode=dataTable&srchLan=-1&p1=-1&p2=9. Accessed September 2016.

[l] Added numbers from federally and provincially inspected establishments. Agriculture and Agri-Food Canada (Annual Goats Slaughtered in Federally and Provincially Inspected Establishments in Canada). Available at: http://www.agr.gc.ca/eng/industry-markets-and-trade/statistics-and-market-information/by-product-sector/red-meat-and-livestock/red-meat-market-information-canadian-industry/by-sector-reports/sheep-lambs-and-goats/goat-slaughtered-in-canada/?id=1415860000044#2014. Accessed October 2017.

[m] Number of animals recorded on January 1st, 2016 Statistics Canada (CANSIM 003-0031). Available at: www5.statcan.gc.ca/cansim/a26?lang=eng&retrLang=eng&id=0030031&tabMode=dataTable&srchLan=-1&p1=-1&p2=9. Accessed October 2017.

Table 3. 6 Detailed information on population numbers, 2016 (continued)

[n] 2010 Canadian Equine Industry Profile Study. Available at: https://www.equestrian.ca/cdn/storage/resources_v2/wf9c32LH4uErLanMs/original/wf9c32LH4uErLanMs.pdf. Accessed October 2017.

[o] Table 003-0001. Available at: www5.statcan.gc.ca/cansim/a26?lang=eng&retrLang=eng&id=0030001&pattern=aquaculture&tabMode=dataTable&srchLan=-1&p1=1&p2=49. Accessed April 2018.

[p] Federal and provincial slaughter. Available at: http://www.agr.gc.ca/eng/industry-markets-and-trade/statistics-and-market-information/by-product-sector/red-meat-and-livestock/red-meat-and-livestock-market-information/supply-sheets-by-species/rabbit-industry-at-a-glance/?id=1415860000120. Accessed May 2016.

[q] Companion Animal Health. Canadian Animal Health Institute. Available at: https://www.cahi-icsa.ca/uploads/userfiles/files/press%20release%20-%20pet%20survey%20-%20january%2011%202017%20cm%20lr.pdf. Accessed October 2017.

[r] Average weights for cats and dogs from French Agency for Food, Environmental and Occupational Health & Safety (ANSES) - French Agency for Veterinary Medicinal Products (ANMV). Sales survey of Veterinary Medicinal Products containing Antimicrobials in France - 2014. Volumes and estimated exposure of animals to antimicrobials. Available at: https://www.anses.fr/en/system/files/ANMV-Ra-Antibiotiques2014EN.pdf. Accessed on May 2016.

[s] Per 2015 and 2016 discussion with Québec swine expert the Canadian average weight of treatment of exported weaner pigs was changed to 3 kg.

Table 3. 7 Quantity of ionophores and chemical coccidiostats (kg) distributed for sale for use in animals, 2007 to 2016

Antimicrobial class aggregation	Quantity of active ingredient (kg)										Change (%) from 2007 to 2016	Change (%) from 2015 to 2016
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016		
Ionophores, chemical anticoccidials, and arsenicals[a]	445,952											
Ionophores, chemical coccidiostats, arsenicals, and nitroimidazoles[a]		472,384	491,152	490,355								
Chemical coccidiostats[a]					22,372							
						18,471						
							45,138	104,332	104,067	85,935	NA	-17%
Ionophores[a]					433,332							
						473,595						
							311,652	462,476	466,888	487,733	NA	4%
Total	**445,952**	**472,384**	**491,152**	**490,355**	**455,704**	**492,066**	**356,790**	**566,808**	**570,955**	**573,668**	**NA**	**0.48%**

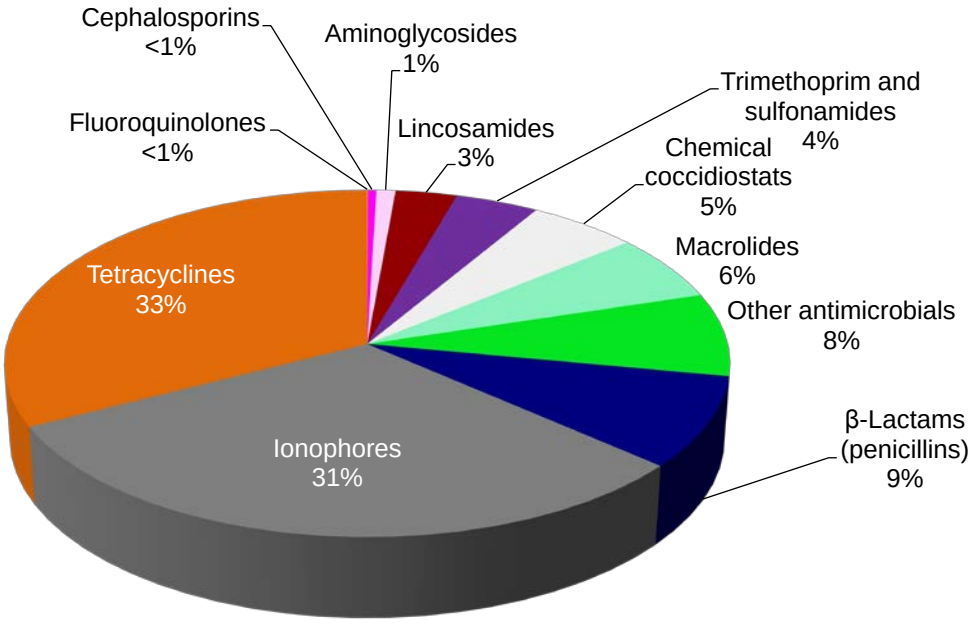
NA = not available or not applicable.

Changes in percentage over time from 2007 to 2016 are relative to the quantities reported in 2007. Changes in percentage over time from 2015 to 2016 are relative to the quantities reported in 2015.

Animal distribution data do not include antimicrobials imported under the “own use” provision or imported as active pharmaceutical ingredients intended for further compounding; hence, are underestimates of total quantities used.

CAHI provides the information according to a “3 company accounting rule” established by CAHI to comply with the European Union and the United States’ anti-competition regulations. CAHI added in some cases a “90% rule” to be sure not to infringe the regulations in the United States. These accounting rules can result in changes to the categorization of specific antimicrobials over time; hence within an antimicrobial category, columns with different colours should not be compared.

Figure 3. 10 Percentages of the quantities (kg of active ingredient) of antimicrobials distributed for sale for use in animals with ionophores and chemical coccidiostats, 2016



Animal distribution data do not include antimicrobials imported under the "own use" provision or imported as active pharmaceutical ingredients intended for further compounding; hence, are underestimates of total quantities used.

"Other antimicrobials" for 2016 included: avilamycin, bacitracins, bambermycin, chloramphenicol, chlorhexidine gluconate, florfenicol, fusidic acid, nitarsone, nitrofurantoin, nitrofurazone, novobiocin, polymixin, tiamulin, and virginiamycin.

Farm Surveillance in broiler chickens

Key findings

One hundred thirty-six sentinel farms were surveyed in 2016. For the program, the flock is the unit of interest and is defined as a group of birds hatched/delivered/placed in a single production unit (barn, floor or pen) on approximately the same day. One unique flock per farm was sampled. Data presented in this section represent 1 broiler grow-out cycle. This means 1 cycle is sampled/farm/year out of a possible 6.5 cycles or barn turnovers normally expected within an average Canadian broiler production unit.

Chicks were sourced from major broiler Canadian Hatcheries Federation members (n = 19) across the country. Ten flocks (7%, 10/136) (Table 3. 8) or 6% of the broiler chicken population sampled (176,784/3,052,498)[54] were classified as raised without antibiotics (RWA) and reported not using any antimicrobials, ionophores, or chemical coccidiostats during the grow-out period. In the conventionally raised flocks antimicrobials administered via feed represented the greatest route of administration/exposure in terms of frequency (93%, 126/136 flocks), mg/PCU (95%, 124/130 mg/PCU)[55], nDDDvetCA/1,000 broiler chicken-days at risk (99%, 572/576 nDDDvetCA/1,000 broiler chicken-days at risk), and nDDDvetCA/PCU (99%, 19.2/19.4 nDDDvetCA/PCU).

Provincial/regional and temporal variations in mg/PCU were noted. Overall, there was a national decrease in mg/PCU; however, the mg/PCU increased in British Columbia by 5% (92 to 97 mg/PCU) and in the Prairies by 25% (128 to 161 mg/PCU) (Figure 3. 11 and Table 3. 10). Provincial/regional and temporal variations in nDDDvetCA/1,000 broiler chicken-days at risk were also noted. There was an overall increase nationally of 8%. Regionally there was a nDDDvetCA/1,000 broiler chicken-days at risk increase in British Columbia of 22% (402 to 492 nDDDvetCA/1,000 broiler chicken-days at risk), in the Prairies of 41% (424 to 599 nDDDvetCA/1,000 broiler chicken-days at risk) and in Québec of 28% (468 to 598 nDDDvetCA/1,000 broiler chicken-days at risk) (Table 3. 10). Regional/provincial trends in 3 AMU indicators are summarized in Figure 3. 11.

Twenty-three percent (31/136) of broiler producers reported that the chicks delivered to their barn were medicated at the hatchery. This reported use at the hatchery is down from 39% in 2015.

There were no broiler producers that reported the use of Category I antimicrobials by any route of administration in 2016 (Table 3. 9); this is consistent with the 2015 data. As in the previous years, the most commonly used antimicrobial was bacitracin (61%, 82/136 flocks) and was included in 41% (216/528 rations) of the total feed rations (including unmedicated); the use of this antimicrobial accounted for 63% (82/130 mg/PCU) of the overall quantity of antimicrobials used in 2016 (Figure 3. 12).

[54] Biomass for 2016 surveillance year (3,052,498) = Total population at chick placement (3,109,531) minus half of the overall reported mortality at pre-harvest sampling day (57,033).

[55] mg/PCU = mg (total milligrams of active ingredient consumed by the flocks included in the survey) divided by the biomass (Population correction unit). Unless indicated, the European Surveillance of Veterinary Antimicrobial Consumption (ESVAC) of 1 kg/bird was used.

Administration in feed

Overall, 93% (126/136) of broiler chicken producers reported AMU in feed (Table 3. 8); the antimicrobials used belonged to Categories II and III, as well as drugs that have no current VDD Category at the time of writing of this report (e.g., avilamycin, an orthosomycin).

There were 461 feed rations reportedly fed in the 2016 questionnaires and of these, 65 rations (12%) were unmedicated (Table 3. 9). Provincial/regional variations in the frequency of AMU were observed in 2016 (Figure 3. 17).

Similar to the previous years the following antimicrobial classes were used across the 4 provinces/region: streptogramins, bacitracins, and orthosomycins (Figure 3. 17). These antimicrobial classes were used for treating enteric diseases such as necrotic enteritis (caused by *Clostridium perfringens*). For most antimicrobial classes (except trimethoprim-sulfadiazine), disease prevention was the most frequently reported reason for use. Similar to the previous surveillance years, trimethoprim-sulfadiazine was largely used for treatment of avian pathogenic *Escherichia coli* (APEC), the classical causative agent of a variety of disease syndromes in broiler chickens including yolksacculitis, septicemia, and respiratory disease/airsacculitis, collectively known as colibacillosis[56]. Compared to 2015, the percentage of broiler producers that reported the use of this antimicrobial decreased by 7% in Ontario (22% to 15%) however use increased by 2% in Québec (17% to 19%); the number of producers reporting trimethoprim-sulfadiazine was significantly higher in this province compared to the other provinces/regions (Figure 3. 17).

There were provincial/regional variations in feed mg/PCU estimates (Figure 3. 18). Similar to 2015, the use of trimethoprim-sulfadiazine contributed to the overall mg/PCU estimates in Québec and Ontario for treatment of diseases (Figure 3. 18).The mg/PCU was relatively higher in the Prairies (145 mg/PCU) and in Québec (130 mg/PCU) compared to the other provinces/regions. In Ontario, mg/PCU decreased from the previous year (175 to 125 mg/PCU).

Provincial/regional variations in nDDDvetCA/1,000 broiler chicken-days at risk was also observed (Figure 3. 19), but unlike in the feed mg/PCU estimates, the nDDDvetCA/1,000 broiler chicken-days at risk was highest in Ontario and the Prairies (601 nDDDvetCA/1,000 broiler chicken-days at risk), followed by Québec (593 nDDDvetCA/1,000 broiler chicken-days at risk). Bacitracins and streptogramins, used for the prevention of necrotic enteritis were the classes that contributed largely to the overall nDDDvetCA/1,000 broiler chicken-days at risk for the surveillance year.

The AMU indicator/indicator, nDDDvetCA/PCU[57] is included in the report for the first time this reporting year and data showed regional/provincial temporal trends similar to the nDDDvetCA/1,000 broiler chicken-days at risk. It was highest in Ontario (21 nDDDvetCA/PCU), followed by the Prairies (20 nDDDvetCA/PCU) (Figure 3. 20).

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[56] Nolan et al. Chapter 18. Colibacillosis. In Diseases of Poultry 13th Ed. Swayne et al (eds). John Wiley and Sons, Ames, Iowa. pp 751-805.

[57] ECDC (European Centre for Disease Prevention and Control), EFSA (European Food Safety Authority), and EMA (European Medicines Agency), 2017. ECDC/EFSA/EMA second joint report on the integrated analysis of the consumption of antimicrobial agents and occurrence of antimicrobial resistance in bacteria from humans and food-producing animals – Joint Interagency Antimicrobial Consumption and Resistance Analysis (JIACRA) Report. EFSA Journal 2017;15(7):4872, 135 pp. doi:10.2903/j.efsa.2017.4872.

Overall, the number of broiler producers reporting AMU for growth promotion was relatively low in 2016 (1 flock that used bambermycin, a flavophospholipid) and contributed less than 1% of the overall quantity of antimicrobials used in 2016 (Figure 1. 12, Table 3. 9).

Administration in water

Eleven percent (15/136) of broiler chicken producers reported AMU in water (Table 3. 8). Similar to last year, 60% (9/15) of the broiler chicken producers that reported antimicrobial use in water consulted a veterinarian or had a veterinary prescription available.

In terms of quantity, antimicrobials administered via water contributed to 4% (5 of 130 mg/PCU) of the total quantity of antimicrobials used in 2016 (Figure 3. 13). There were no broiler chicken producers that reported the use of antimicrobials belonging to Category I in water. In addition, unlike in feed, antimicrobials used in water were used for the treatment of systemic diseases. In terms of nDDDvetCA/1,000 broiler chicken-days at risk and nDDDvetCA/PCU, antimicrobial use in water contributed less than or equal to 1% to the total number (4/576 nDDDvetCA/1,000 broiler chicken-days at risk; 0.13/19.4 nDDDvetCA/PCU) (Table 3. 9).

Administration *in ovo* or subcutaneous injection

For 2 consecutive years (2015 to 2016) there were no producers reporting the use of ceftiofur in chicks at the hatcheries in any province/region (Figure 3. 27).

Gentamicin use in British Columbia decreased from 40% (10/25) in 2015 to 6% (2/32) in 2016. This drop in gentamicin use in British Columbia corresponded with the decrease in the proportion of flocks that were not medicated from 40% (10/25) to 91% (29/32).

The proportion of flocks medicated with lincomycin-spectinomycin in Québec increased from 83% (20/26) in 2015 to 88% (23/26) in 2016; the use of this antimicrobial combination in Québec was significantly higher compared to all other provinces/regions in 2016 (Figure 3. 27). The increase in the use of lincomycin-spectinomycin may have an impact on treatment success as a recent Canadian study showed that the use of lincomycin-spectinomycin in young chicks may select for gentamicin resistance in APEC[58].

The reported reason for any hatchery-level antimicrobial use was for disease prevention. In 2016, the contribution of antimicrobials administered at the hatchery level relative to all route of administration was less than or equal to 1% (0.1 mg/PCU; 0.2 nDDDvetCA/1,000 broiler chicken-days at risk; 0.01/19.4 nDDDvetCA/PCU) (Table 3. 9).

Ionophores, chemical coccidiostats and other antiprotozoal agents

These agents belong to Veterinary Drugs Directorate's Category IV antimicrobials or not yet categorized (e.g., chemical coccidiostats, pyrimethamine) and have low importance to human medicine. In 2016, these products contributed to 63% of the total antimicrobial exposure in the broiler flock population sampled. Among the coccidiostats, the most frequently used was

[58] Chalmers G, Cormiera AC, Nadeau M, Côté G, Reid-Smith RJ, Boerlin P. Determinants of virulence and of resistance to ceftiofur, gentamicin, and spectinomycin in clinical *Escherichia coli* from broiler chickens in Québec, Canada. Vet Microbiol. 2017;203:149-157. Available at: http://www.sciencedirect.com/science/article/pii/S0378113516304837?via%3Dihub.

the ionophore-chemical coccidiostat combination drug, narasin-nicarbazin (45%, 61/136) and was included in 27% of all the coccidiostat-medicated rations delivered to the producer (134/496 rations[59]). The overall frequency of ionophore and chemical coccidiostat use in feed appeared to be stable in the last 4 years of surveillance (Figure 3. 31) but there were provincial and temporal variations in coccidiostat use (Figure 3. 32 and Figure 3. 33).

Summary of antimicrobials used by routes of administration

Table 3. 8 Number of broiler flocks with reported antimicrobial use by route of administration, 2016

Antimicrobial use	Route of administration			
	Any route[a] n (%)	*In ovo*/subcutaneous n (%)	Feed n (%)	Water n (%)
Any antimicrobial use	126 (93)	31 (23)	126 (93)	15 (11)
No antimicrobial use[b]	10 (7)	105 (77)	10 (7)	121 (89)
Total flocks	**136 (100)**	**136 (100)**	**136 (100)**	**136 (100)**

[a] Flocks with reported use of an antimicrobial class by feed, water, *in ovo*/subcutaneous, or any combination of these routes are included in each count.

[b] These were antibiotic-free, organic and a conventional flock that were fed unmedicated feed rations and no medications in water throughout the grow-out period. The proportion of flocks sampled that were antibiotic-free (were not exposed to antibiotics and coccidiostats) and organic in certain provinces may not be representative of the volume of birds raised under these management practices in that participating province or nationally.

[59] This is the total number of feed rations that contained ionophores and chemical coccidiostats.

Table 3. 9 Frequency and quantity of antimicrobial use in broiler chickens, 2016

Route of administration	Antimicrobial	Flocks n (%)	Ration n (%)	Days exposed median (min. ; max.)[a]	Level of drug median (min. ; max.)[b]	Quantity of antimicrobial active ingredient[c]		
						mg/PCU	nDDDvetCA/ 1,000 Broiler chicken-days at risk	nDDDvetCA/ PCU
Feed					g/tonne			
II	Tylosin	10 (7)	21 (4)	9 (5 ; 14)	22 (22 ; 44)	3	3	0.10
	Penicillin G procaine	12 (9)	23 (4)	8 (6 ; 19)	33 (22 ; 66)	4	24	0.80
	Virginiamycin	38 (28)	90 (17)	8 (1 ; 19)	22 (11 ; 44)	14	139	4.67
	Trimethoprim sulfadiazine	11 (8)	12 (2)	5 (3 ; 14)	300 (200 ; 300)	11	48	1.63
III	Bacitracin	82 (61)	216 (41)	8 (1 ; 21)	55 (50 ; 110)	82	240	8.11
IV	Bambermycin	1 (1)	2 (< 1)	7 (6 ; 7)	2 (2 ; 2)	< 0.1		
N/A	Avilamycin	47 (35)	97 (19)	8 (1 ; 17)	15 (15 ; 30)	11	117	3.95
No AMU in feed		10 (7)	65 (12)					
Total feed, medicated		**126 (93)**	**461 (87)**			**124**	**572**	**19.26**
Water					g/Liter			
II	Amoxicillin	2 (1)	2	5 (5 ; 5)	0.1 (0.1 ; 0.1)	0.2	1	0.02
	Penicillin G potassium	4 (3)	5	4 (2 ; 5)	0.2 (0.2 ; 0.2)	0.6	0.4	0.01
	Penicillin-streptomycin	2 (1)	2	4 (3 ; 5)	0.1 (0.1 ; 0.1)	0.3	1	0.02
III	Sulfamethazine	2 (1)	1	2 (2 ; 2)	1 (1 ; 1)	2	0.3	0.01
	Sulfaquinoxaline	3 (2)	3	3 (2 ; 4)	0.4 (0.4 ; 0.4)	1	0.5	0.02
	Sufaquinoxaline-pyrimethamine	2 (1)	2	5 (3 ; 6)	0.2 (0.2 ; 0.2)	1	5	0.16
	Tetracycline-neomycin	2 (1)	2	3 (3 ; 3)	0.3 (0.3 ; 0.3)	0.7	1	0.03
No AMU in water		121 (89)						
Total water, medicated		**13 (9)**	**17**			**5**	**4**	**0.13**
Injection					mg/egg or chick			
II	Gentamicin	4 (3)			0.2	0	< 0.1	0.00
	Lincomycin-spectinomycin	27 (20)			0.75	0.1	0.2	0.01
No AMU via injection		**105 (77)**						
Total injection		**31 (23)**				**0.1**	**0.2**	**0.01**
All routes[d]						**130**	**576**	**19.35**

See corresponding page for footnotes.

Table 3. 9 Frequency and quantity of antimicrobial use in broiler chickens, 2016 (continued)

Roman numerals II to IV indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

N/A = not applicable (no classification available at the time of writing of this report).

ESVAC = European Surveillance of Veterinary Antimicrobial Consumption.

AMU = antimicrobial use.

Combination antimicrobials include the values for both antimicrobial components.

Grey shaded cells = no data or calculations/values are not applicable for broilers.

mg/PCU = milligrams/population correction unit.

DDDvetCA = Canadian Defined Daily Doses for animals (average labelled dose) in milligrams per kilogram broiler chicken per day (mg_{drug}/kg_{animal}/day); please refer to Appendix: Supplemental data, Table A. 1 for the list of standards.

nDDDvetCA/1,000 broiler chicken-days at risk = number of DDDvetCA/1,000 broiler chicken-days at risk.

nDDDvetCA/PCU = number of DDDvetCA/population correction unit.

For detailed metric description, please refer to Table 3. 1.

[a] Days exposed are by ration (not full grow-out) or 1 course of water treatment.

[b] Level of drug is in grams/tonne of feed or grams/liter drinking water. In water, “grams” is the inclusion rate multiplied by the concentration of the drug in that product. In chicks or hatching eggs, level of drug is in milligrams per chick or hatching egg, as reported by the veterinarian/producer.

[c] Total quantity of antimicrobials were calculated based on feed or water consumed (feed and water were estimated based on breed standards).

[d] The final mg/PCU, nDDDvetCA/1,000 broiler chicken-days at risk and nDDDvetCA/PCU exclude coccidiostats and pyrimethamine. Flavophospholipids was included only in the mg/PCU.

Table 3. 10 Production, biomass and quantity of antimicrobials used by province/region, 2013 to 2016

Province/ region	Year	Number of flocks	Preharvest weight	Age sampled	Active ingredient	Broiler weights	mg/PCU		nDDDvetCA/1,000 broiler chicken-days at risk		nDDDvetCA/PCU	
			mean (kg)	mean (days)	(mg)	(kg)[b]	Total	%change[c]	Total	%change[c]	Total	%change[c]
British Columbia	2013	26	1.9	33	54,261,569	522,525	104		482		16	
	2014	30	1.9	33	67,501,580	650,756	104	0	379	-21	12	-22
	2015	25	2.0	33	54,447,865	592,652	92	-11	402	6	13	9
	2016	32	2.0	33	73,759,200	765,987	96	5	492	22	16	21
Prairies	2013	15	1.7	33	58,408,347	453,936	129		481		16	
	2014	37	1.9	34	153,398,813	910,594	168	31	447	-7	15	-6
	2015	38	1.9	34	95,772,902	746,106	128	-24	424	-5	14	-6
	2016	38	1.9	34	137,911,267	857,215	161	25	607	43	20	42
Ontario	2013	30	2.4	38	132,209,361	740,183	179		687		26	
	2014	42	2.2	36	172,264,675	999,661	172	-4	629	-8	22	-14
	2015	49	2.4	38	227,842,085	1,204,851	189	10	678	8	25	13
	2016	40	2.2	36	112,172,080	884,702	127	-33	604	-11	21	-15
Québec	2013	28	1.9	33	80,394,607	581,995	138		633		21	
	2014	34	2.0	33	109,661,081	739,406	148	7	592	-7	20	-6
	2015	24	1.8	33	68,033,382	491,834	138	-7	468	-21	15	-22
	2016	26	1.9	33	72,716,755	544,595	134	-3	598	28	19	27
National[a]	2013	99	2.0	34	325,273,884	2,298,639	142		590		20	
	2014	143	2.0	34	502,826,150	3,300,417	152	8	523	-11	18	-13
	2015	136	2.1	35	446,096,233	3,035,442	147	-4	534	2	18	5
	2016	136	2.0	34	396,559,302	3,052,498	130	-12	576	8	19	5

In the analysis above, there was a slight adjustment to the 2014 mg/PCU data due to flock population correction for Québec (153 to 152 mg/PCU).

mg/PCU = milligrams/population correction unit

ESVAC = European Surveillance of Veterinary Antimicrobial Consumption.

DDDvetCA = Canadian Defined Daily Doses for animals (average labelled dose) in milligrams per kilogram broiler chicken per day (mg_{drug}/kg_{animal}/day); please refer to Appendix: Supplemental data, Table A. 1 for the list of standards.

nDDDvetCA/1,000 broiler chicken-days at risk = number of DDDvetCA/1,000 broiler chicken-days at risk.

nDDDvetCA/PCU = number of DDDvetCA/population correction unit.

For detailed indicator description, please refer to Table 3. 1.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

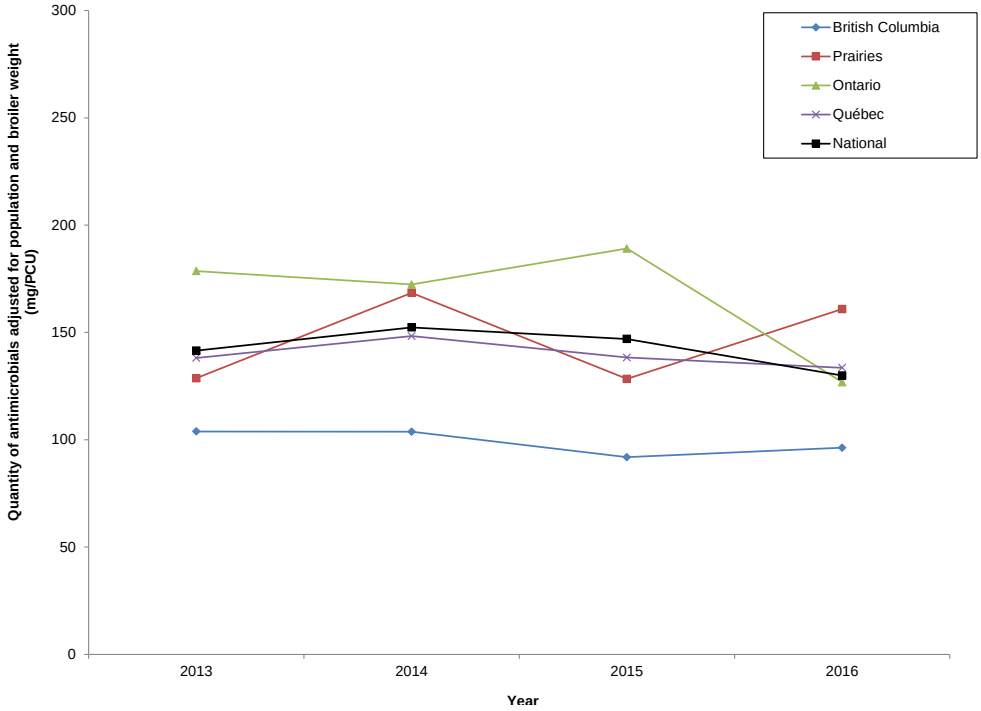
[a] Population correction unit (PCU) or biomass, European weight (total flock population x ESVAC standard weight of 1 kg bird).

[b] Percent change = [(current surveillance year – previous surveillance year)/previous surveillance year] x 100.

[c] Includes only the provinces/regions surveyed and combines the quantity of antimicrobials used in feed, water and injection excluding coccidiostats, antiprotozoals and flavophospholipids.

Figure 3. 11 Antimicrobial use indicators temporal trends, 2013 to 2016

a) mg/PCU



b) nDDDvetCA/1,000 broiler chicken-days at risk

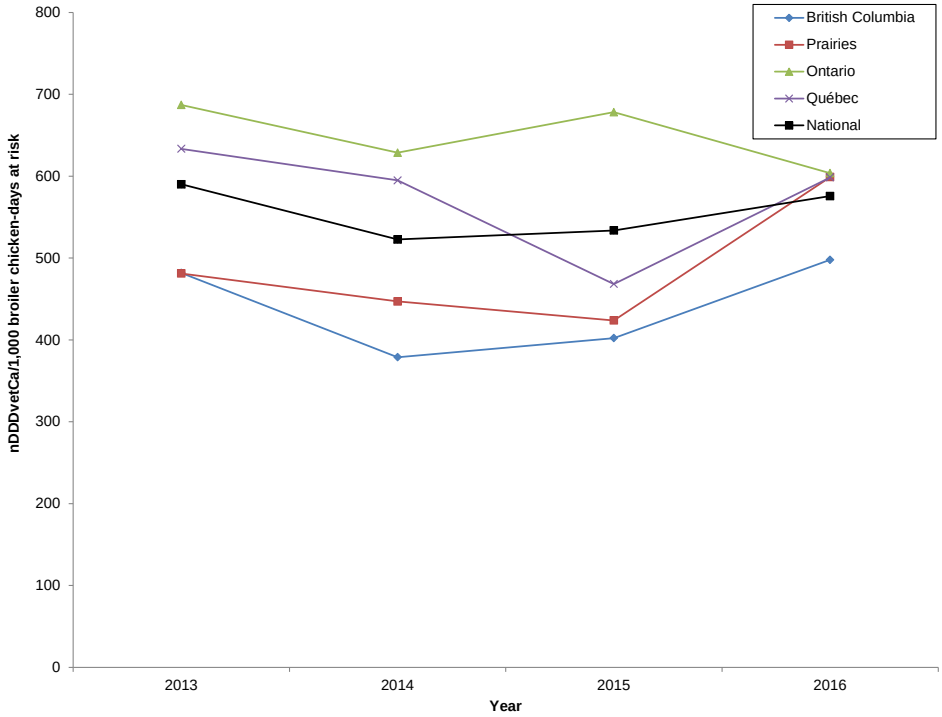
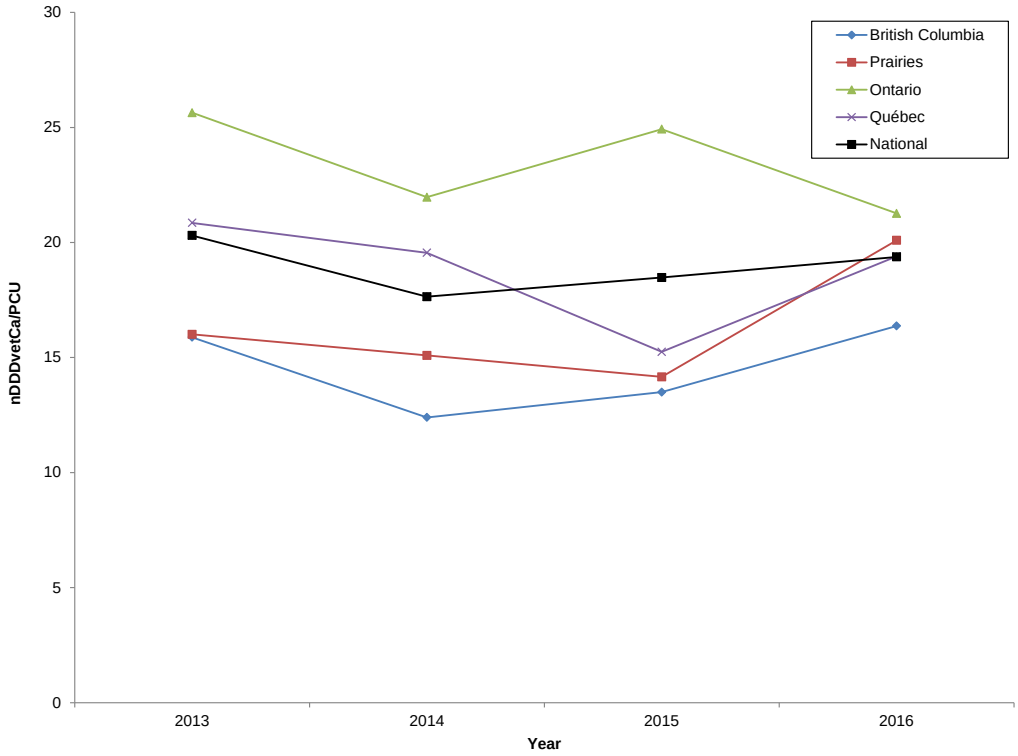


Figure 3. 11 Antimicrobial use indicators temporal trends, 2013 to 2016 (continued)

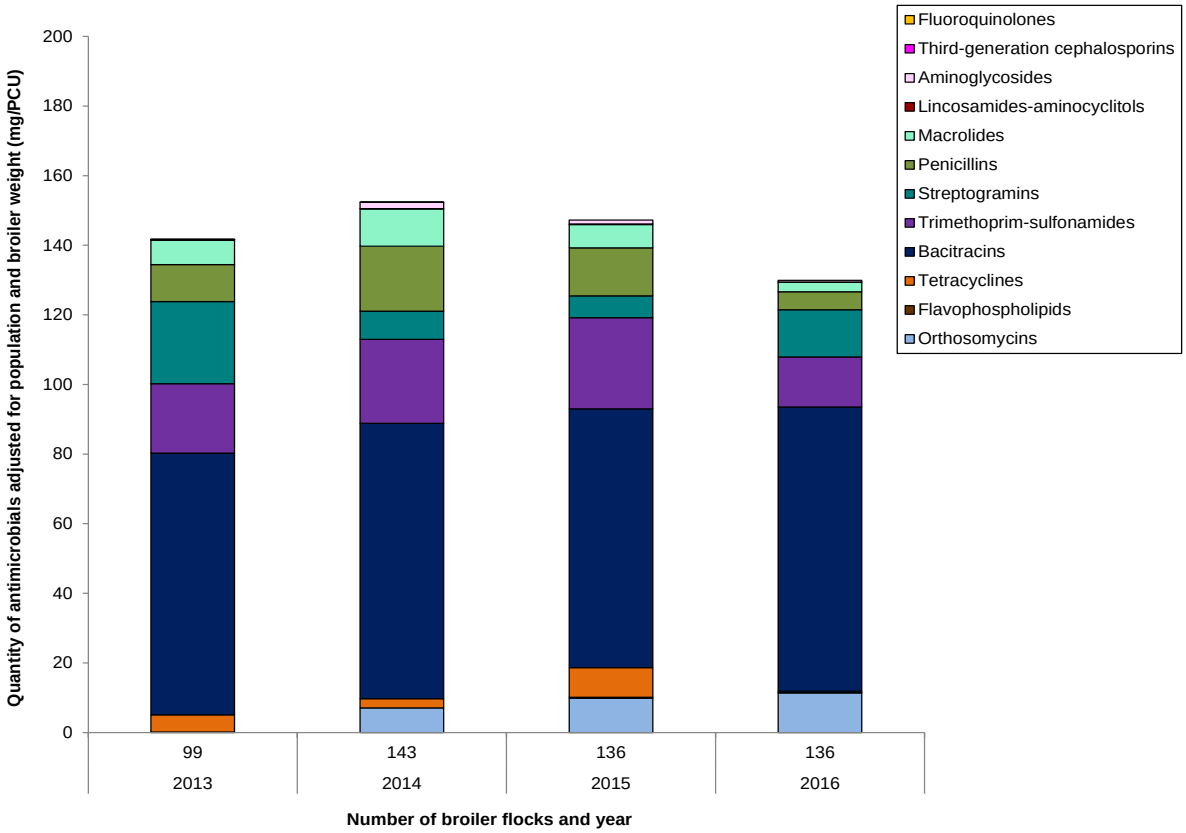
c) nDDDvet/PCU



Regional/provincial and national data used in figures above are presented in Table 3. 10.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Figure 3. 12 Quantity of antimicrobial use in all routes of administration, adjusted for population and broiler weight (mg/PCU), 2013 to 2016



Year	2013	2014	2015	2016
Number of flocks	99	143	136	136
Antimicrobial class				
I Fluoroquinolones	< 0.1	0	0	0
I Third-generation cephalosporins	< 0.1	< 0.1	0	0
II Aminoglycosides	< 0.1	2	1	0.5
II Lincosamides-aminocyclitols	0.1	0.1	0.2	0.1
II Macrolides	7	11	7	3
II Penicillins	11	19	14	5
II Streptogramins	24	8	6	14
II Trimethoprim and sulfonamides	20	24	26	14
III Bacitracins	75	79	74	82
III Tetracyclines	5	3	8	0
IV Flavophospholipids	0.2	0	0.3	< 0.1
N/A Orthosomycins	0	7	10	11
Total	**142**	**152**	**147**	**130**

Roman numerals I to IV indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate. N/A = not applicable (no classification available at the time of writing of this report).

Flavophospholipids intended for growth promotion and had lower dosing than prevention or treatment dosing was not included in the estimates.

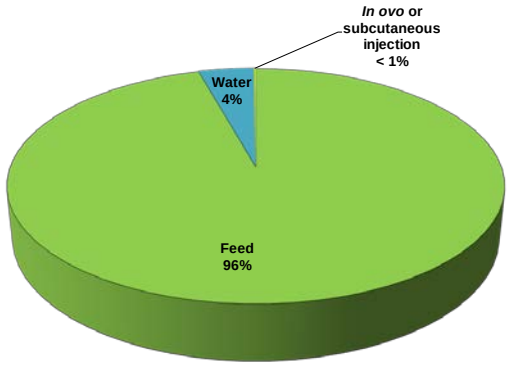
mg/PCU = milligrams/population correction unit.

In the analysis above, there was an adjustment to the 2014 mg/PCU data due to flock population correction for Québec (153 to 152 mg/PCU).

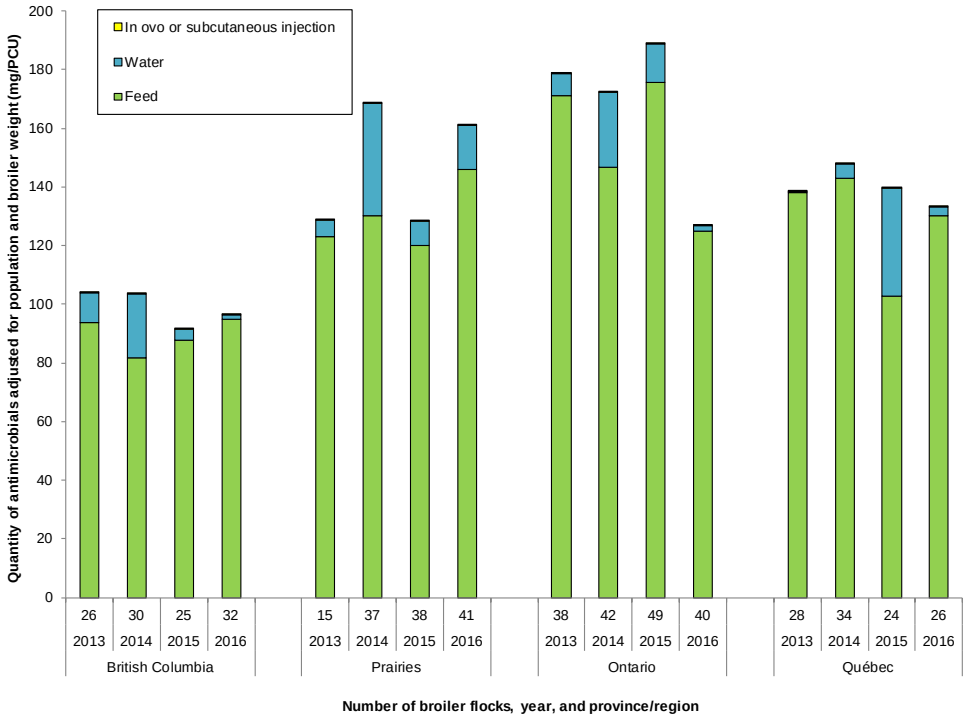
For detailed indicator description, please refer to Table 3. 1.

Figure 3. 13 Quantity of antimicrobials, adjusted for population and broiler weight (mg/PCU), in 2016 and by province/region, 2013 to 2016

a) 2016



b) by province/region



Province/region	British Columbia				Prairies				Ontario				Québec			
Year	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016
Number of flocks	26	30	25	32	15	37	38	38	30	42	49	40	28	34	24	26
Route of administration																
Feed	94	82	88	95	123	130	120	146	171	147	175	125	138	143	103	130
Water	10	22	4	1	5	38	8	15	8	26	13	2	1	5	37	3
In ovo or subcutaneous injections	0.1	0.1	0.3	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.0	0.3	0.4	0.4	0.5
Total	**104**	**104**	**92**	**96**	**129**	**168**	**128**	**161**	**179**	**172**	**189**	**127**	**139**	**148**	**140**	**134**

See corresponding footnotes on next page.

Figure 3. 13 Quantity of antimicrobials, adjusted for population and broiler weight (mg/PCU), in 2016 and by province/region, 2013 to 2016 (continued)

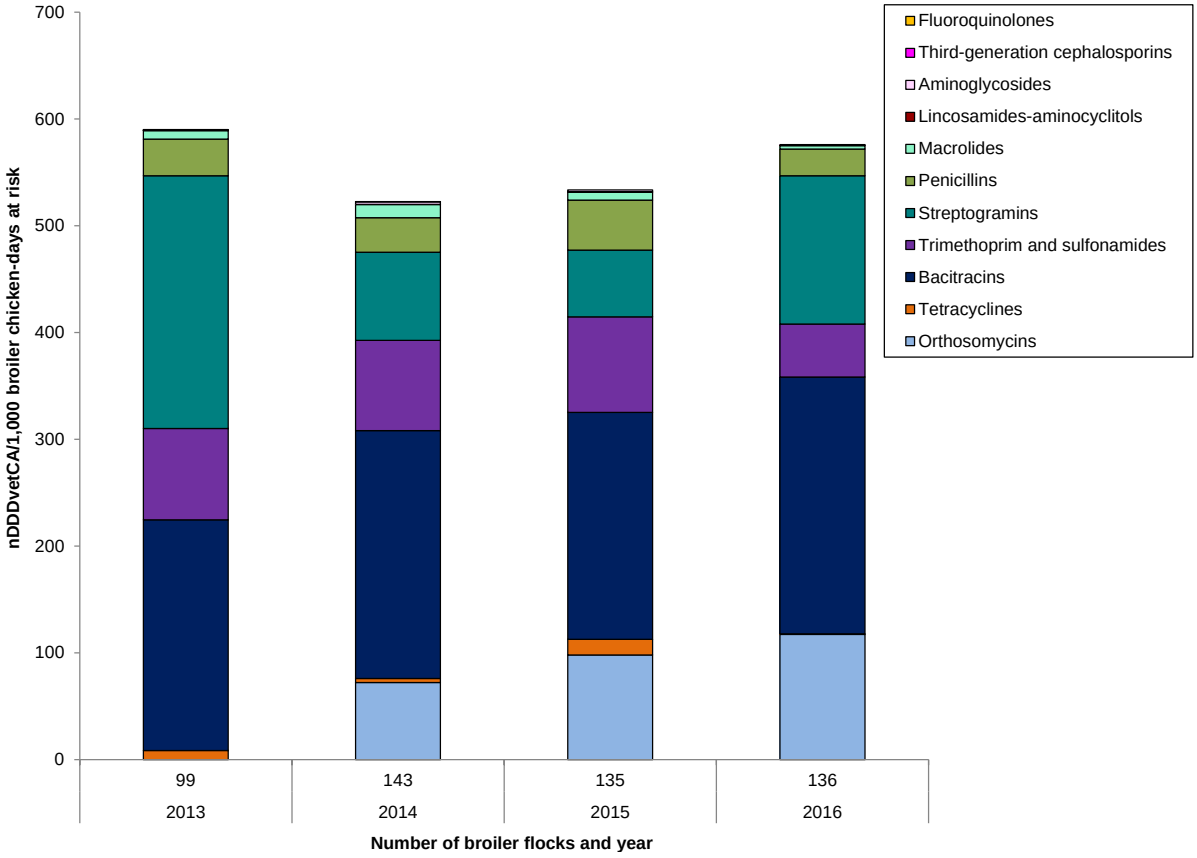
Ionophores, chemical coccidiostats and flavophospholipids used in feed and antiprotozoals used in water (e.g., pyrimethamine, a diaminopyrimidine) were excluded in the estimates above.

mg/PCU = milligrams/population correction unit.

For detailed indicator description, please refer to Table 3. 1.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Figure 3. 14 Number of Canadian Defined Daily Doses for animals per 1,000 broiler chicken-days at risk (nDDDvetCA/1,000 broiler chicken-days at risk) for all routes of administration, 2013 to 2016



Year Number of flocks		2013 99	2014 143	2015 136	2016 136
Antimicrobial class					
I	Fluoroquinolones	< 0.1	0	0	0
	Third-generation cephalosporins	1	0.1	0	0
II	Aminoglycosides	< 0.1	2	2	1
	Lincosamides-aminocyclitols	0.3	0.3	1	0.4
	Macrolides	8	12	7	3
	Penicillins	34	32	47	25
	Streptogramins	237	83	63	139
	Trimethoprim and sulfonamides	85	84	89	50
III	Bacitracins	216	232	213	240
	Tetracyclines	9	4	15	1
N/A	Orthosomycins	0	72	98	117
Total		**590**	**523**	**534**	**576**

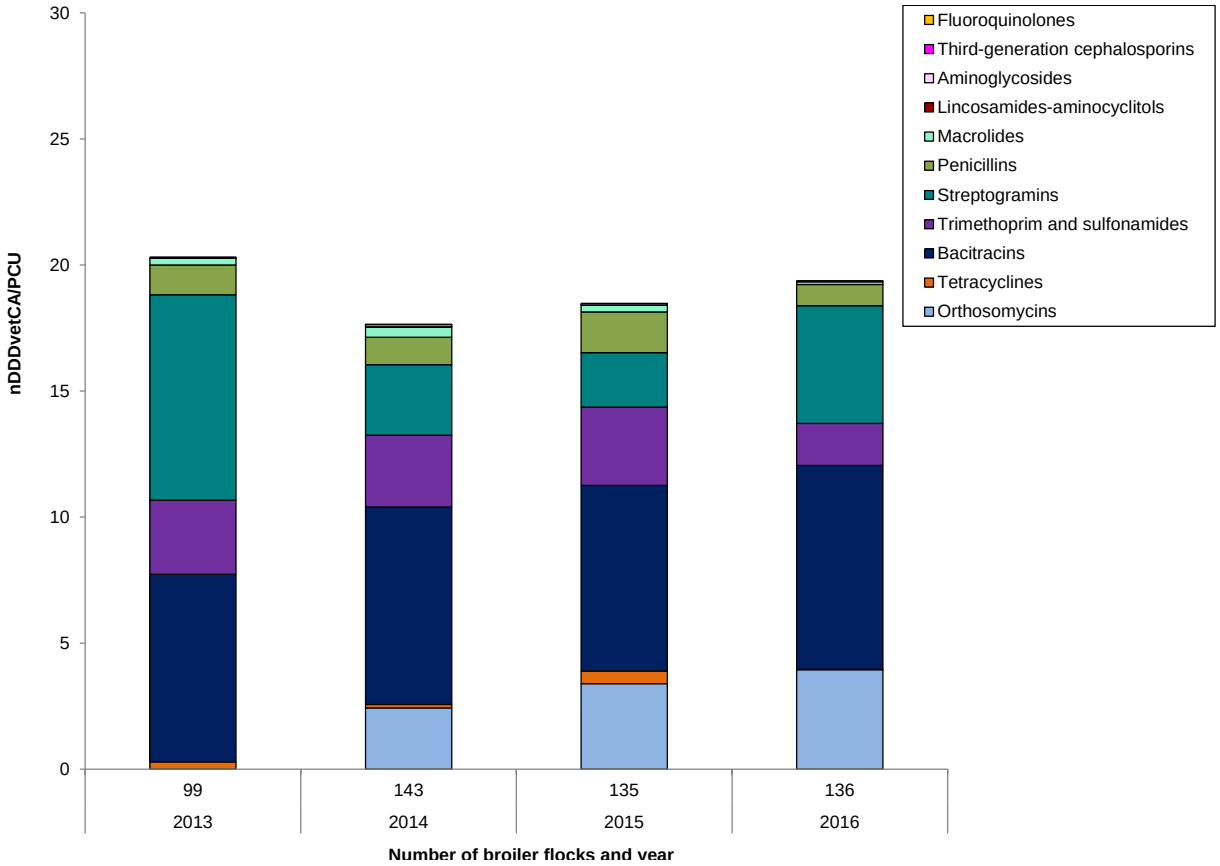
Roman numerals I to III indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate. N/A = not applicable (no classification available at the time of writing of this report).

DDDvetCA = Canadian Defined Daily Doses for animals (average labelled dose) in milligram per kilogram broiler weight per day (mg_{drug}/kg_{animal}/day); please refer to Appendix: Supplemental data, Table A. 1 for the list of standards.

nDDDvetCA/1,000 broiler chicken-days at risk = Number of DDDvetCA/1,000 broiler chicken-days at risk.

For detailed indicator description, please refer to Table 3. 1.

Figure 3. 15 Number of Canadian Defined Daily Doses for animals per population correction unit (nDDDvetCA/PCU) for all routes of administration, 2013 to 2016



Year Number of flocks		2013 99	2014 143	2015 136	2016 136
Antimicrobial class					
I	Fluoroquinolones	< 0.1	0	0	0
	Third-generation cephalosporins	< 0.1	< 0.1	0	0
II	Aminoglycosides	< 0.1	< 0.1	< 0.1	< 0.1
	Lincosamides-aminocyclitols	< 0.1	< 0.1	< 0.1	< 0.1
	Macrolides	0.3	0.4	0.3	0.1
	Penicillins	1.2	1.1	1.6	0.8
	Streptogramins	8.1	2.8	2.2	4.7
	Trimethoprim and sulfonamides	2.9	2.9	3.1	1.7
III	Bacitracins	7.4	7.8	7.4	8.1
	Tetracyclines	0.3	0.1	0.5	< 0.1
N/A	Orthosomycins	0.0	2.4	3.4	3.9
Total		**20.3**	**17.6**	**18.5**	**19.4**

Roman numerals I to III indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate. N/A = not applicable (no classification at the time of writing of this report).

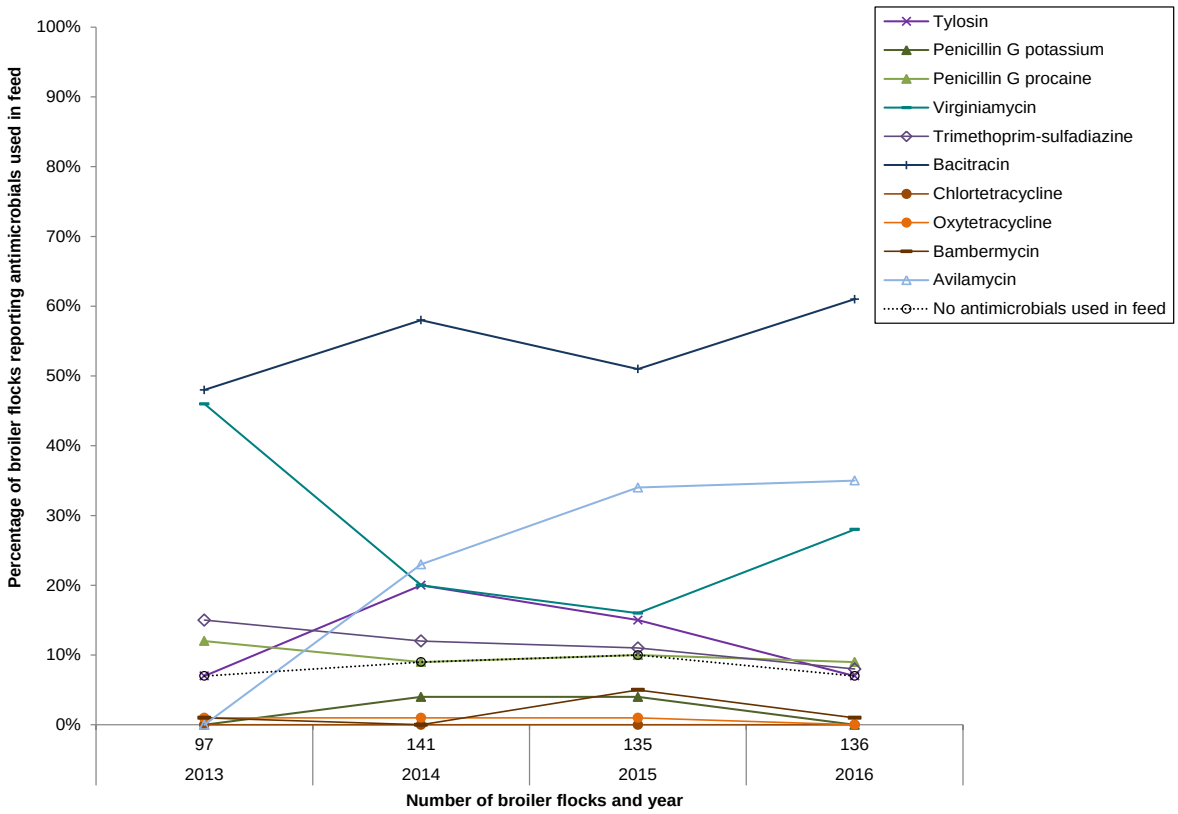
DDDvetCA = Canadian Defined Daily Doses for animals (average labelled dose) in milligram per kilogram broiler weight per day (mg_{drug}/kg_{animal}/day); please refer to Appendix: Supplemental data, Table A. 1 for the list of standards.

nDDDvetCA/PCU = number of DDDvetCA/population correction unit.

For detailed indicator description, please refer to Table 3. 1.

Antimicrobial use in feed by frequency

Figure 3. 16 Percentage of broiler flocks reporting antimicrobial use in feed, 2013 to 2016



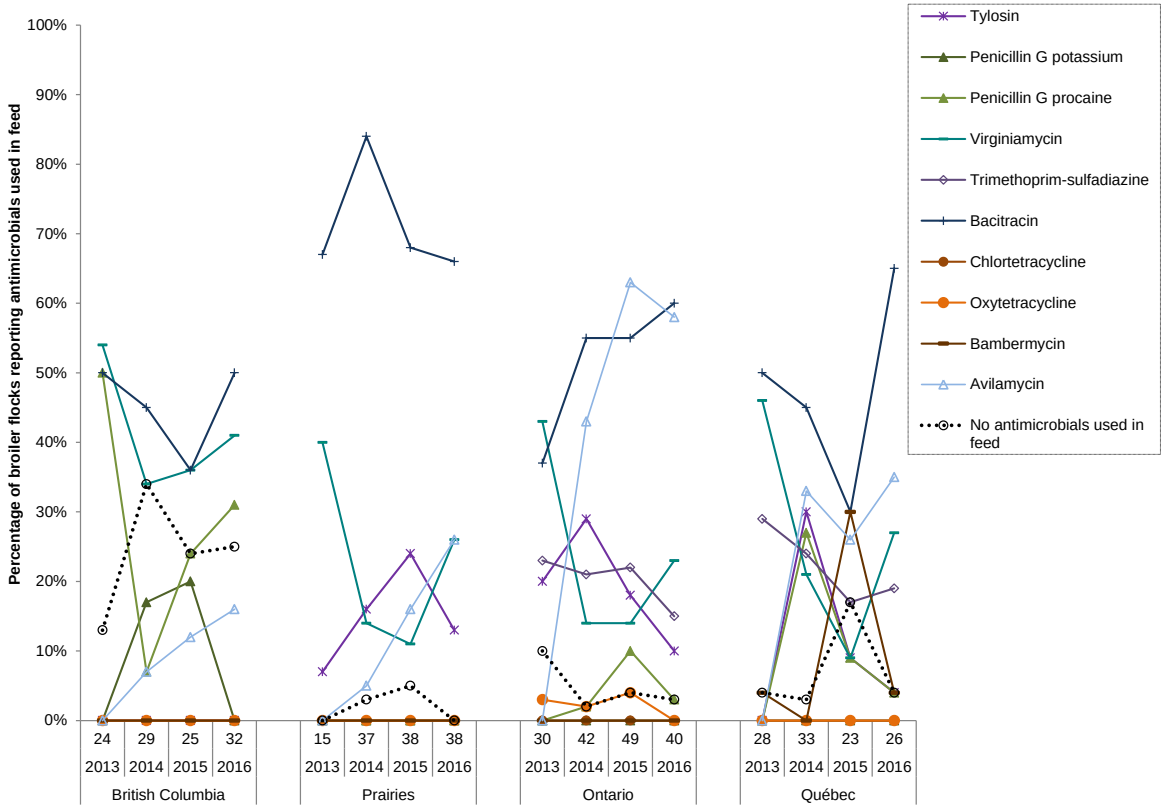
Year	2013	2014	2015	2016
Number of flocks	97	141	135	136
Antimicrobial class				
II Tylosin	**7%**	20%	**15%**	**7%**
II Penicillin G potassium	**0%**	4%	**4%**	**0%**
II Penicillin G procaine	**12%**	9%	**10%**	**9%**
II Virginiamycin	**46%**	20%	**16%**	**28%**
II Trimethoprim-sulfadiazine	**15%**	12%	**11%**	**8%**
III Bacitracin	**48%**	58%	**51%**	**61%**
III Chlortetracycline	**0%**	0%	**0%**	**0%**
III Oxytetracycline	**1%**	1%	**1%**	**0%**
IV Bambermycin	**1%**	0%	**5%**	**1%**
N/A Avilamycin	**0%**	23%	**34%**	**35%**
No antimicrobials used in feed	**7%**	9%	**10%**	**7%**

Roman numerals II to IV indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate. N/A = not applicable (no classification at the time of writing of this report).

Numbers per column may not add up to 100% as some flocks may have used an antimicrobial more than once or used multiple antimicrobials throughout the grow-out period.

For the temporal analyses, the proportion (%) of flocks using a specific antimicrobial in the current year has been compared to the proportion (%) of flocks using the same antimicrobial in the first and the previous surveillance year (grey areas). The presence of blue areas indicates significant temporal differences ($P \leq 0.05$) for a given antimicrobial.

Figure 3. 17 Percentage of broiler flocks reporting antimicrobial use in feed by province / region, 2013 to 2016



Province/region		British Columbia				Prairies				Ontario				Québec			
Year		2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016
Number of flocks		24	29	25	32	15	37	38	38	30	42	49	40	28	33	23	26
Antimicrobial																	
	Tylosin	0%	0%	0%	0%	7%	16%	24%	13%	20%	29%	18%	10%	0%	30%	9%	4%
	Penicillin G potassium	0%	17%	20%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
II	Penicillin G procaine	50%	7%	24%	31%	0%	0%	0%	0%	0%	2%	10%	3%	0%	27%	9%	4%
	Virginiamycin	54%	34%	36%	41%	40%	14%	11%	26%	43%	14%	14%	20%	46%	21%	9%	27%
	Trimethoprim-sulfadiazine	0%	0%	0%	0%	0%	0%	0%	0%	23%	21%	22%	15%	29%	24%	17%	19%
	Bacitracin	50%	45%	36%	50%	67%	84%	66%	66%	37%	55%	55%	60%	50%	45%	30%	65%
III	Chlortetracycline	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Oxytetracycline	0%	0%	0%	0%	0%	0%	0%	0%	3%	2%	4%	0%	0%	0%	0%	0%
IV	Bambermycin	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	0%	30%	4%
N/A	Avilamycin	0%	7%	12%	16%	0%	5%	16%	26%	0%	43%	63%	58%	0%	33%	26%	35%
	No antimicrobials used in feed	13%	34%	24%	25%	0%	3%	5%	0%	10%	2%	4%	3%	4%	3%	17%	4%

Roman numerals II to IV indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate. N/A = not applicable (no classification at the time of writing of this report).

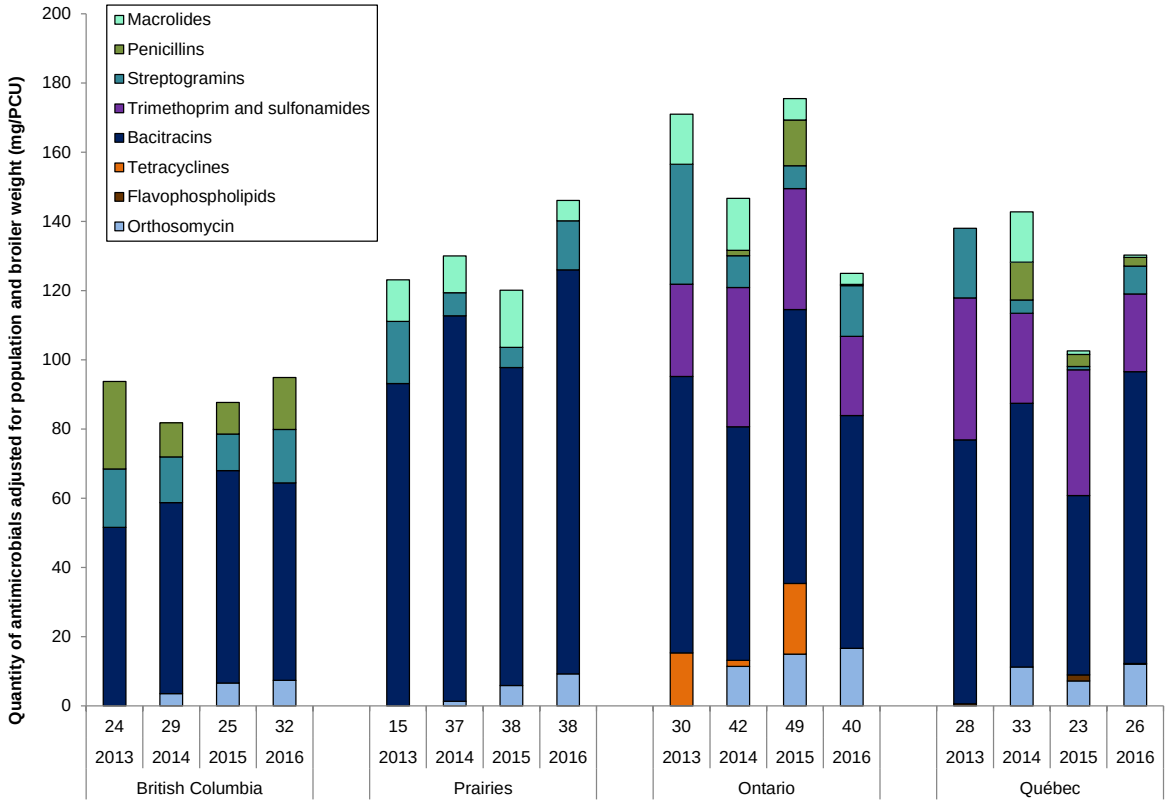
Numbers per column may not add up to 100% as some flocks may have used an antimicrobial more than once or used multiple antimicrobials throughout the grow-out period.

For the temporal analyses within province/region, the proportion (%) of flocks using a specific antimicrobial in the current year has been compared to the proportion (%) of flocks using the same antimicrobial in the first and the previous surveillance year (grey areas). The presence of blue areas indicates significant temporal differences within province/region ($P \leq 0.05$) for a given antimicrobial. The presence of red areas indicates significant provincial/regional differences ($P \leq 0.05$) for a given antimicrobial within the current year. The presence of purple areas (2016 surveillance year; Québec-referent province) indicates significant temporal and provincial/regional differences ($P \leq 0.05$) for a given antimicrobial.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Antimicrobials use in feed by quantitative indicators

Figure 3. 18 Quantity of antimicrobial use in feed adjusted for population and broiler weight (mg/PCU), 2013 to 2016



Number of broiler flocks, year, and province/region

Province/region		British Columbia				Prairies				Ontario				Québec			
Year		2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016
Number of flocks		24	29	25	32	15	37	38	38	30	42	49	40	28	33	23	26
Antimicrobial class																	
II	Macrolides	0	0	0	0	12	11	16	6	14	15	6	3	0	15	1	1
II	Penicillins	25	10	9	15	0	0	0	0	0	2	13	0	0	11	3	2
II	Streptogramins	17	13	11	15	18	7	6	14	35	9	7	15	20	4	1	8
II	Trimethoprim and sulfonamides	0	0	0	0	0	0	0	0	27	40	35	23	41	26	36	23
III	Bacitracins	52	55	61	57	93	111	92	117	80	68	79	67	76	76	52	84
III	Tetracyclines	0	0	0	0	0	0	0	0	15	2	20	0	0	0	0	0
IV	Flavophospholipids	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0
N/A	Orthosomycins	0	4	7	7	0	1	6	9	0	11	15	17	0	11	7	12
Total		**94**	**82**	**88**	**95**	**123**	**130**	**120**	**146**	**171**	**147**	**175**	**125**	**138**	**143**	**103**	**130**

Roman numerals II to IV indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate. N/A = not applicable (no classification at the time of writing of this report).

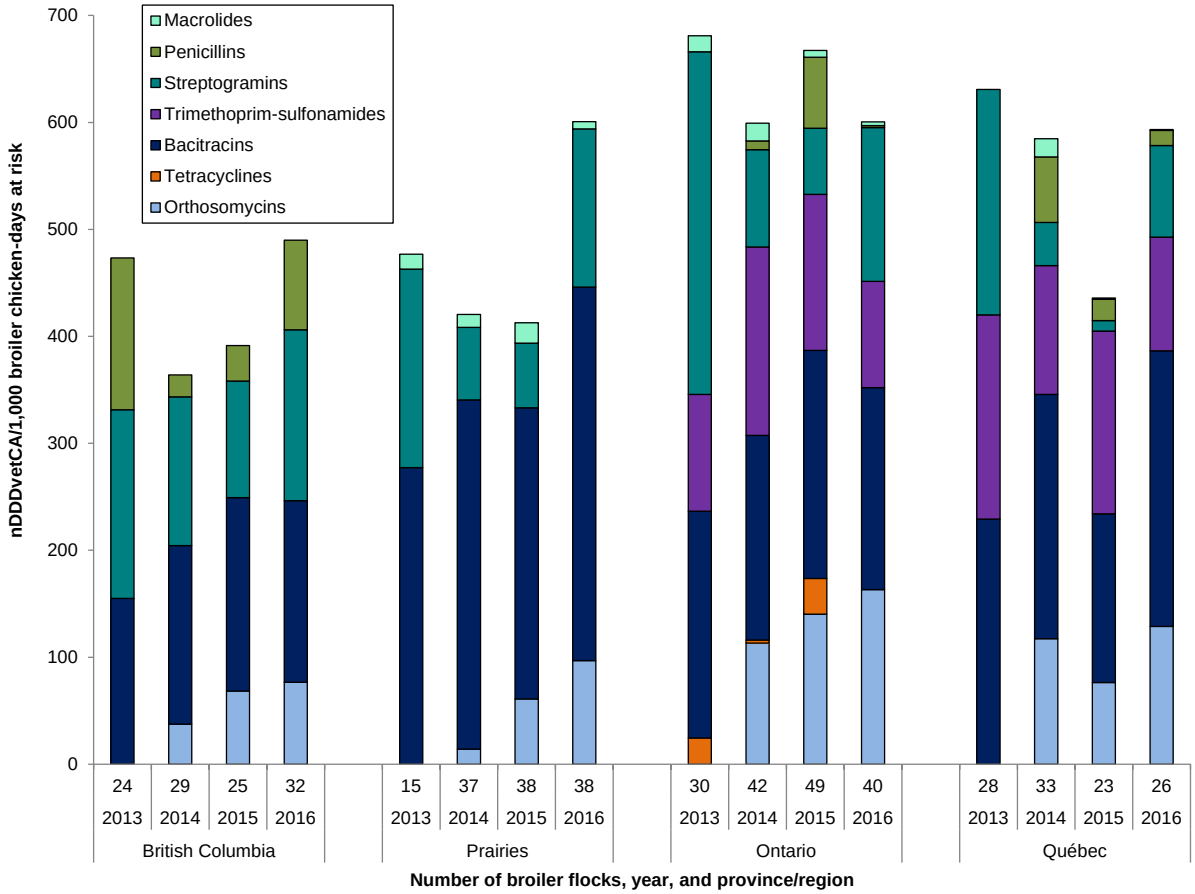
Flavophospholipids intended for growth promotion and had lower dosing than prevention or treatment dosing was not included in the estimates.

mg/PCU = milligrams/population correction unit.

For detailed indicator description, please refer to Table 3. 1.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Figure 3. 19 Number of Canadian Defined Daily Doses for animals per 1,000 broiler chicken-days at risk (nDDDvetCA/1,000 broiler chicken-days at risk) for antimicrobials administered in feed, 2013 to 2016



Province/region		British Columbia				Prairies				Ontario				Québec			
Year		2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016
Number of flocks		24	29	25	32	15	37	38	38	30	42	49	40	28	33	23	26
Antimicrobial class																	
II	Macrolides	0	0	0	0	14	12	19	7	15	16	6	4	0	17	1	1
	Penicillins	142	20	33	84	0	0	0	0	0	8	66	2	0	61	20	14
	Streptogramins	176	139	109	160	186	68	60	148	320	91	62	144	211	40	10	86
	Trimethoprim and sulfonamides	0	0	0	0	0	0	0	0	109	176	146	99	191	120	171	106
III	Bacitracins	155	167	181	170	277	327	272	349	212	191	213	189	229	228	158	258
	Tetracyclines	0	0	0	0	0	0	0	0	25	3	33	0	0	0	0	0
N/A	Orthosomycins	0	38	68	77	0	14	61	97	0	113	140	163	0	117	76	129
Total		**473**	**364**	**391**	**490**	**477**	**421**	**413**	**601**	**681**	**599**	**667**	**601**	**631**	**585**	**436**	**593**

Roman numerals II to III indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate. N/A = not applicable (no classification at the time of writing of this report).

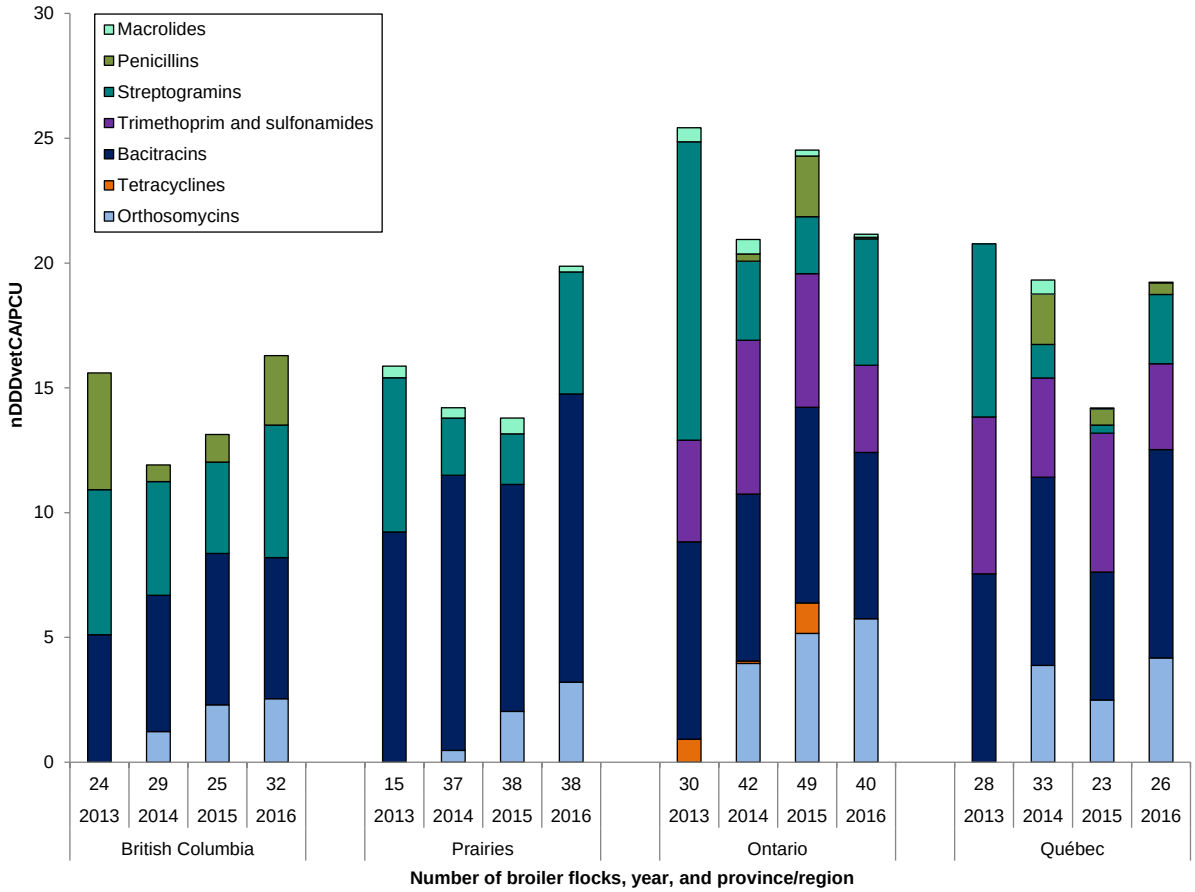
DDDvetCA = Canadian Defined Daily Doses for animals (average labelled dose) in milligram per kilogram broiler weight per day (mg_{drug}/kg_{animal}/day); please refer to Appendix: Supplemental data, Table A. 1 for the list of standards.

nDDDvetCA/1,000 broiler chicken-days at risk = number of DDDvetCA/1,000 broiler chicken-days at risk.

For detailed indicator description, please refer to Table 3. 1.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Figure 3. 20 Number of Canadian Defined Daily Doses for animals per population correction unit (nDDDvetCA/PCU) for antimicrobials administered in feed, 2013 to 2016



Province/region		British Columbia				Prairies				Ontario				Québec			
Year		2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016
Number of flocks		24	29	25	32	15	37	38	38	30	42	49	40	28	33	23	26
Antimicrobial class																	
II	Macrolides	0	0	0	0	0	0	1	0	1	1	0	0	0	1	0	0
	Penicillins	5	1	1	3	0	0	0	0	0	0	2	0	0	2	1	0
	Streptogramins	6	5	4	5	6	2	2	5	12	3	2	5	7	1	0	3
	Trimethoprim and sulfonamides	0	0	0	0	0	0	0	0	4	6	5	3	6	4	6	3
III	Bacitracins	5	5	6	6	9	11	9	12	8	7	8	7	8	8	5	8
	Tetracyclines	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
N/A	Orthosomycins	0	1	2	3	0	0	2	3	0	4	5	6	0	4	2	4
Total		**16**	**12**	**13**	**16**	**16**	**14**	**14**	**20**	**25**	**21**	**25**	**21**	**21**	**19**	**14**	**19**

Roman numerals II to III indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate. N/A = not applicable (no classification at the time of writing of this report).

DDDvetCA = Canadian Defined Daily Doses for animals (average labelled dose) in milligram per kilogram broiler weight per day (mg_{drug}/kg_{animal}/day); please refer to Appendix: Supplemental data, Table A. 1 for the list of standards.

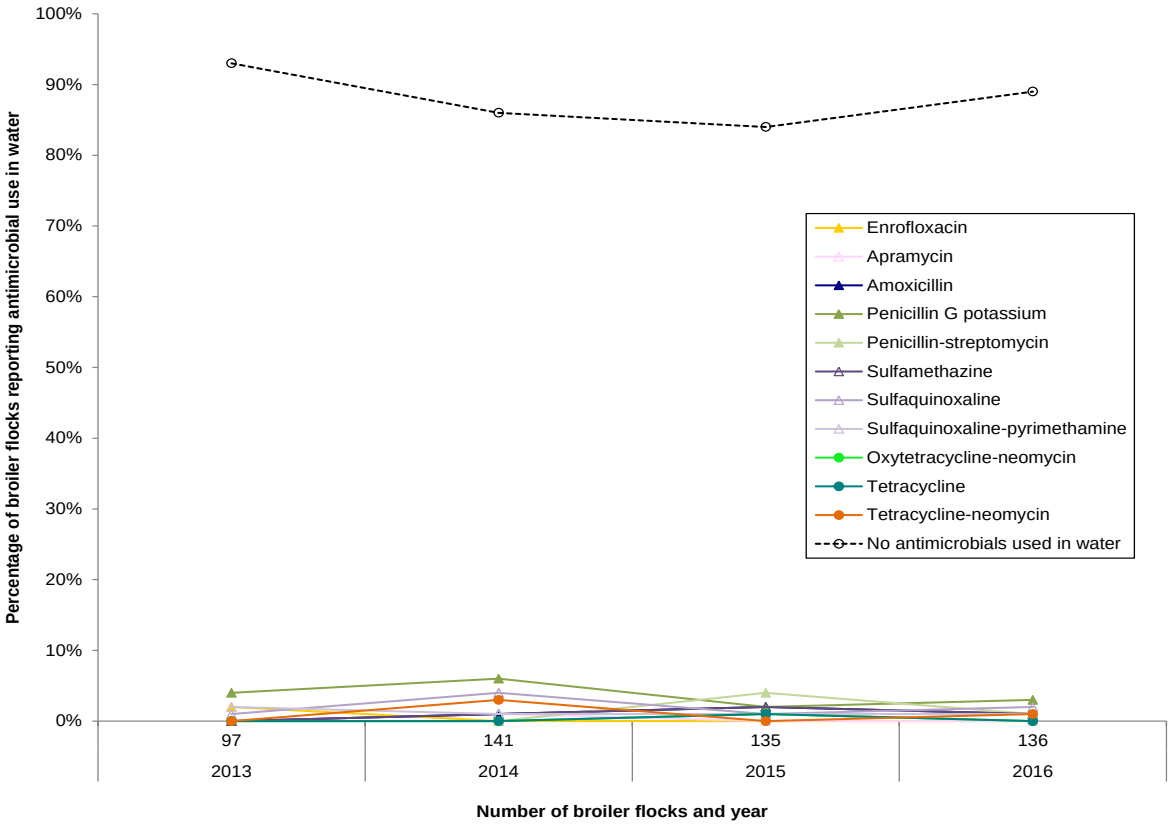
nDDDvetCA/PCU = number of DDDvetCA/population correction unit.

For detailed indicator description, please refer to Table 3. 1.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Antimicrobial use in water by frequency

Figure 3. 21 Percentage of broiler flocks reporting antimicrobial use in water, 2013 to 2016



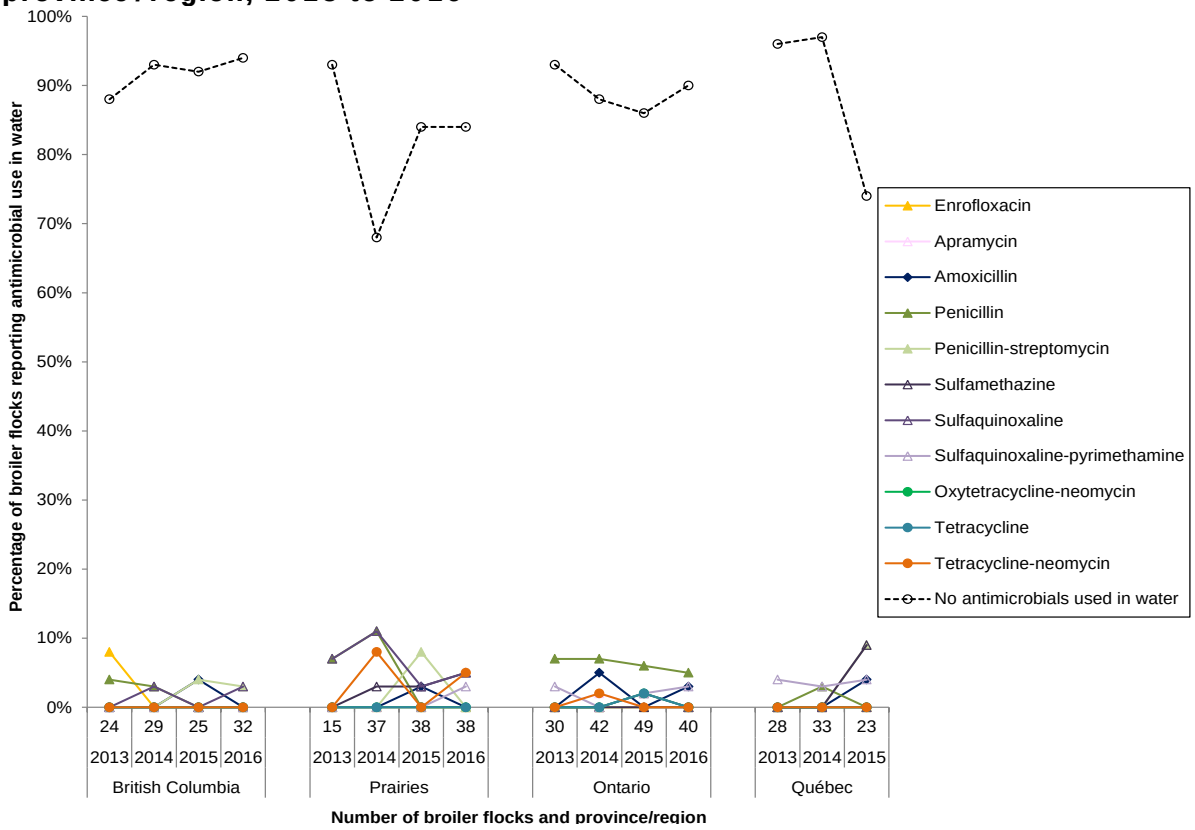
Year		2013	2014	2015	2016
Number of flocks		97	141	135	136
Antimicrobial					
I	Enrofloxacin	**2%**	0%	**0%**	**0%**
II	Apramycin	**0%**	1%	**0%**	**0%**
	Amoxicillin	**0%**	1%	**2%**	**1%**
	Penicillin G potassium	**4%**	6%	**2%**	**3%**
	Penicillin-streptomycin	**0%**	0%	**4%**	**1%**
III	Sulfamethazine	**0%**	1%	**2%**	**1%**
	Sulfaquinoxaline	**1%**	4%	**1%**	**2%**
	Sulfaquinoxaline-pyrimethamine	**2%**	1%	**1%**	**1%**
	Oxytetracycline-neomycin	**0%**	0%	**1%**	**0%**
	Tetracycline	**0%**	0%	**1%**	**0%**
	Tetracycline-neomycin	**0%**	3%	**0%**	**1%**
	No antimicrobials used in water	**93%**	86%	**84%**	**89%**

Roman numerals I to III indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

Numbers per column may not add up to 100% as some flocks have used an antimicrobial more than once or used multiple antimicrobials throughout the growing period.

For the temporal analysis, the proportion (%) of flocks using a specific antimicrobial in the current year has been compared to the proportion (%) of flocks using the same antimicrobial in the first and previous surveillance year (grey areas). The presence of blue areas indicates significant temporal differences ($P \leq 0.05$) for a given antimicrobial.

Figure 3. 22 Percentage of broiler flocks reporting antimicrobial use in water by province/region, 2013 to 2016



Province/region		British Columbia				Prairies				Ontario				Québec			
Year		2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016
Number of flocks		24	29	25	32	15	37	38	38	30	42	49	40	28	33	23	26
Antimicrobial																	
I	Enrofloxacin	**8%**	0%	**0%**	**0%**	**0%**	0%	**0%**	**0%**	**0%**	0%	**0%**	**0%**	**0%**	0%	**0%**	**0%**
II	Apramycin	**0%**	0%	**0%**	**0%**	**0%**	0%	**0%**	**0%**	**0%**	2%	**0%**	**0%**	**0%**	0%	**0%**	**0%**
	Amoxicillin	**0%**	0%	**4%**	**0%**	**0%**	0%	**3%**	**0%**	**0%**	5%	**0%**	**3%**	**0%**	0%	**4%**	**4%**
	Penicillin G potassium	**4%**	3%	**0%**	**0%**	**7%**	11%	**0%**	**0%**	**7%**	7%	**6%**	**5%**	**0%**	3%	**0%**	**8%**
	Penicillin-streptomycin	**0%**	0%	**4%**	**3%**	**0%**	0%	**8%**	**0%**	**0%**	0%	**0%**	**0%**	**0%**	0%	**9%**	**4%**
III	Sulfamethazine	**0%**	0%	**0%**	**0%**	**0%**	3%	**3%**	**5%**	**0%**	0%	**0%**	**0%**	**0%**	0%	**9%**	**0%**
	Sulfaquinoxaline	**0%**	3%	**0%**	**3%**	**7%**	11%	**3%**	**5%**	**0%**	0%	**2%**	**0%**	**0%**	0%	**0%**	**0%**
	Sulfaquinoxaline-pyrimethamine	**0%**	0%	**0%**	**0%**	**0%**	0%	**0%**	**3%**	**3%**	0%	**2%**	**3%**	**4%**	3%	**4%**	**0%**
	Oxytetracycline-neomycin	**0%**	0%	**0%**	**0%**	**0%**	0%	**0%**	**0%**	**0%**	0%	**2%**	**0%**	**0%**	0%	**0%**	**0%**
	Tetracycline	**0%**	0%	**0%**	**0%**	**0%**	0%	**0%**	**0%**	**0%**	0%	**2%**	**0%**	**0%**	0%	**0%**	**0%**
	Tetracycline-neomycin	**0%**	0%	**0%**	**0%**	**0%**	8%	**0%**	**5%**	**0%**	2%	**0%**	**0%**	**0%**	0%	**0%**	**0%**
	No antimicrobials used in water	**88%**	93%	**92%**	**94%**	**93%**	68%	**84%**	**84%**	**93%**	88%	**86%**	**90%**	**96%**	97%	**74%**	**88%**

Roman numerals I to III indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

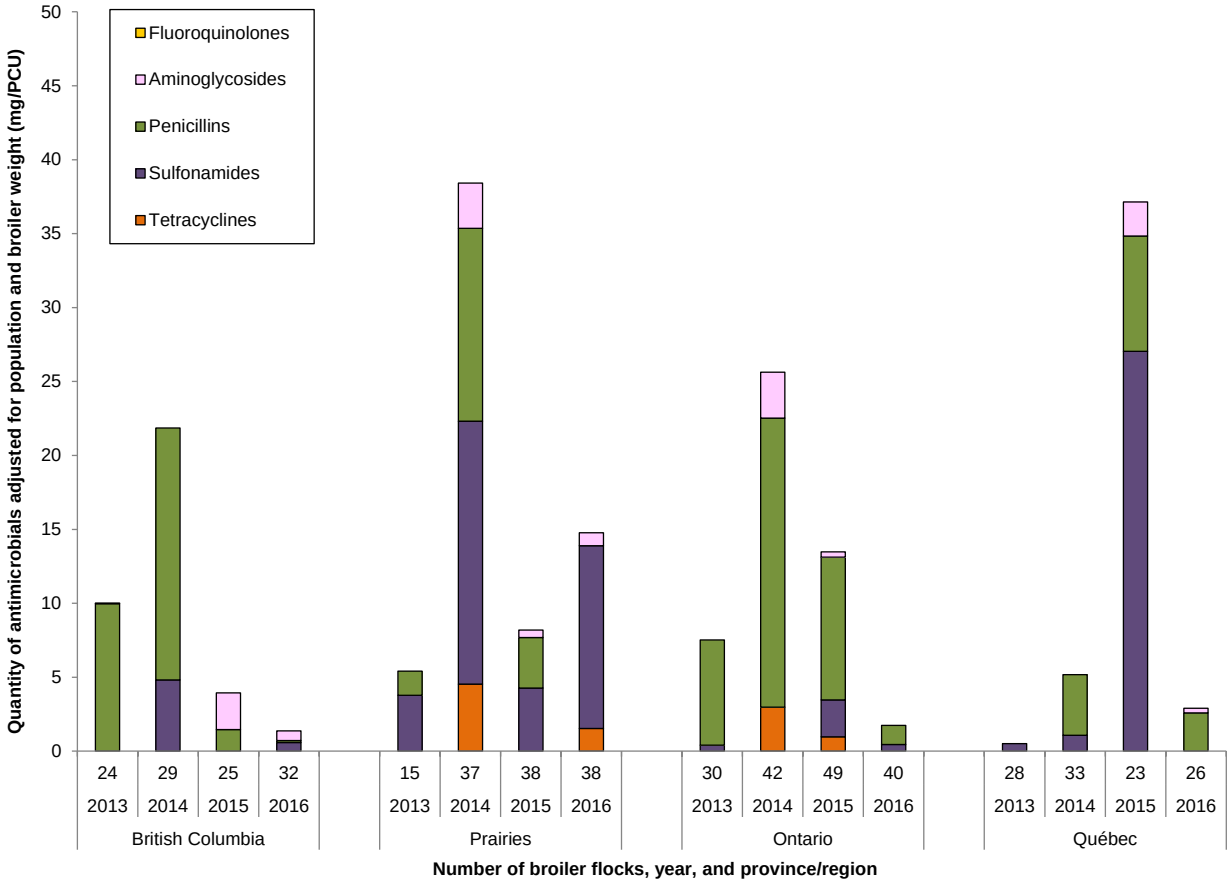
Numbers per column may not add up to 100% as some flocks have used an antimicrobial more than once or used multiple antimicrobials throughout the growing period.

For the temporal analyses within province/region, the proportion (%) of flocks using a specific antimicrobial in the current year has been compared to the proportion (%) of flocks using the same antimicrobial in the first and the previous surveillance year (grey areas). The presence of blue areas indicates significant temporal differences within province/region ($P \leq 0.05$) for a given antimicrobial. The presence of red areas indicates significant provincial/regional differences ($P \leq 0.05$) for a given antimicrobial within the current year. The presence of purple areas (2016 surveillance year; Québec-referent province) indicates significant temporal and provincial/regional differences ($P \leq 0.05$) for a given antimicrobial.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Antimicrobials use in water by quantitative indicators

Figure 3. 23 Quantity of antimicrobial use in water adjusted for population and broiler weight (mg/PCU), 2013 to 2016



Province/region	British Columbia				Prairies				Ontario				Québec			
Year	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016
Number of flocks	24	29	25	32	15	37	38	38	30	42	49	40	28	33	23	26
Antimicrobial class																
I Fluoroquinolones	< 0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
II Aminoglycosides	0	0	2	1	0	3	1	1	0	3	1	0	0	0	2	0.3
II Penicillins	10	17	1	0.1	2	13	3	0	7	20	10	1	0	4	8	3
III Sulfonamides	0	5	0	1	4	18	4	12	0	0	2	0	1	1	27	0
III Tetracyclines	0	0	0	0	0	5	0	2	0	3	1	0	0	0	0	0
Total	**10**	**22**	**4**	**1**	**5**	**38**	**8**	**15**	**8**	**26**	**13**	**2**	**1**	**5**	**37**	**3**

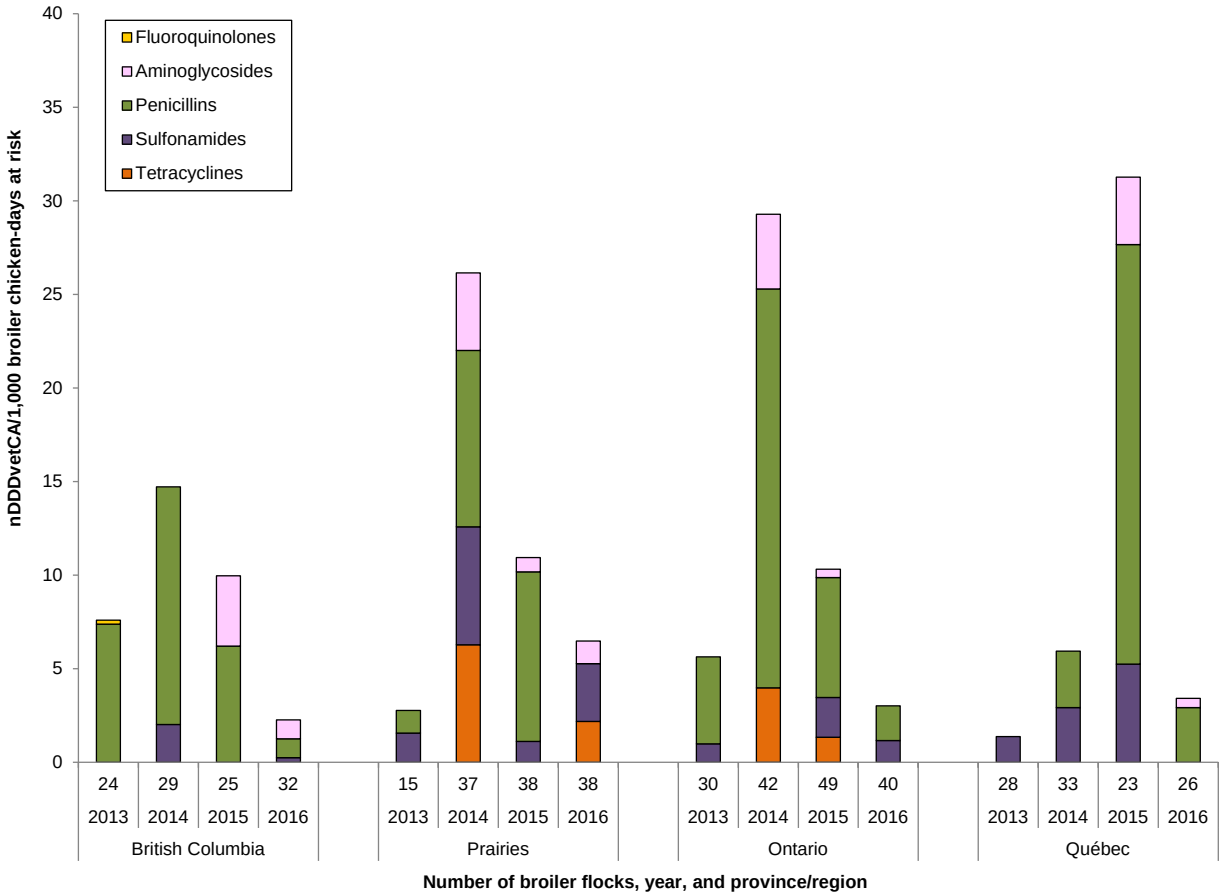
Roman numerals I to III indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

mg/PCU = milligrams/population correction unit.

For detailed indicator description, please refer to Table 3. 1.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Figure 3. 24 Number of Canadian Defined Daily Doses for animals per 1,000 broiler chicken-days at risk (nDDDvetCA/1,000 broiler chicken-days at risk) for antimicrobials administered in water, 2013 to 2016



Province/region	British Columbia				Prairies				Ontario				Québec			
Year	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016
Number of flocks	24	29	25	32	15	37	38	38	30	42	49	40	28	33	23	26
Antimicrobial class																
I Fluoroquinolones	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
II Aminoglycosides	0	0	4	1	0	4	1	1	0	4	0	0	0	0	4	0
II Penicillins	7	13	6	1	1	9	9	0	5	21	6	2	0	3	22	3
III Sulfonamides	0	2	0	< 1	2	6	1	3	1	0	2	1	1	3	5	0
III Tetracyclines	0	0	0	0	0	6	0	2	0	4	1	0	0	0	0	0
Total	**8**	**15**	**10**	**2**	**3**	**26**	**11**	**6**	**6**	**29**	**10**	**3**	**1**	**6**	**31**	**3**

Roman numerals I to III indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

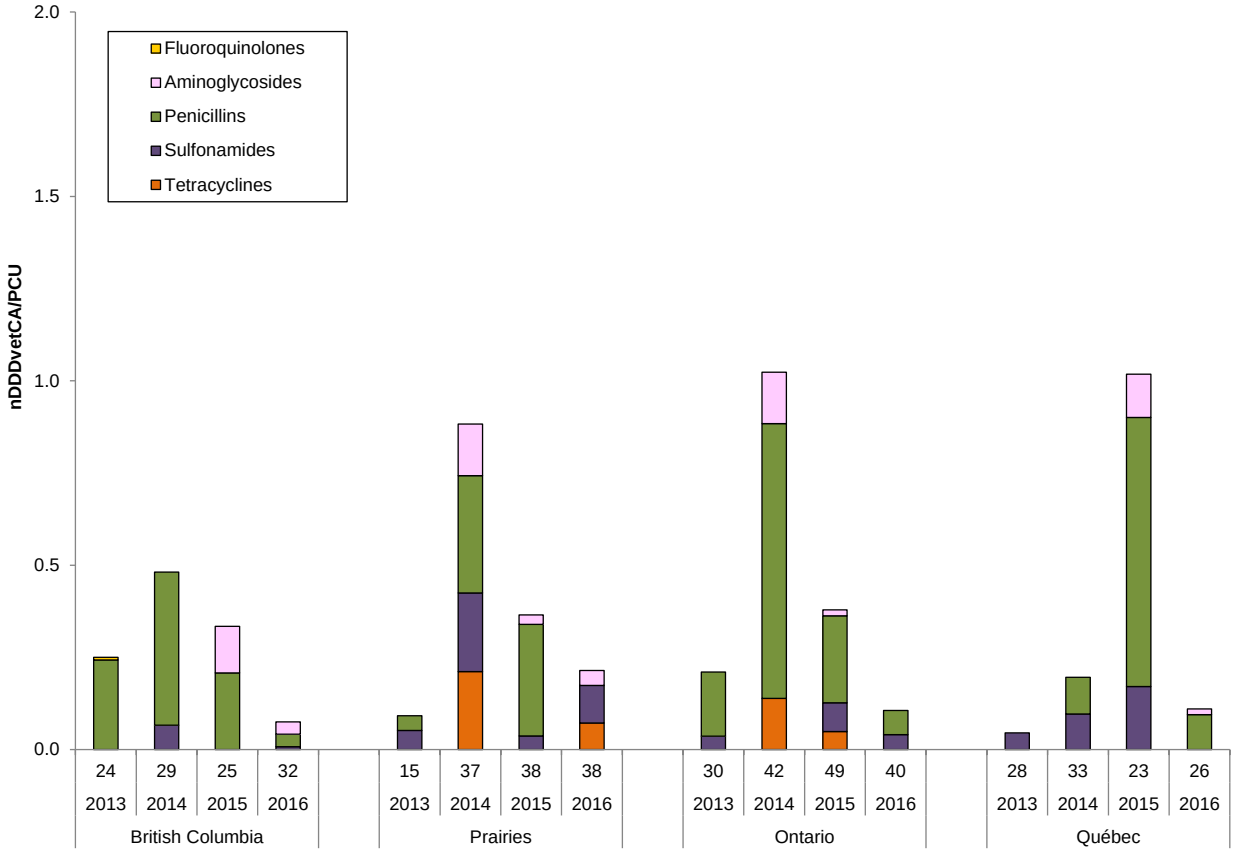
DDDvetCA = Canadian Defined Daily Doses for animals (average labelled dose) in milligram per kilogram broiler weight per day (mg_{drug}/kg_{animal}/day); please refer to Appendix: Supplemental data, Table A. 1 for the list of standards.

nDDDvetCA/1,000 broiler chicken-days at risk = number of DDDvetCA/1,000 broiler chicken-days at risk .

For detailed indicator description, please refer to Table 3. 1.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Figure 3. 25 Number of Canadian Defined Daily Doses for animals per population correction unit (nDDDvetCA/PCU), for antimicrobials administered in water, 2013 to 2016



Province/region	British Columbia				Prairies				Ontario				Québec			
Year	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016
Number of flocks	24	29	25	32	15	37	38	38	30	42	49	40	28	33	23	26
Antimicrobial class																
I Fluoroquinolones	< 0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
II Aminoglycosides	0	0	0.1	0	0	0.1	0	0	0	0.1	0	0	0	0	0.1	0
II Penicillins	0.2	0.4	0.2	0	0	0.3	0.3	0	0.2	0.7	0.2	0.1	0	0.1	0.7	0.1
III Sulfonamides	0	0.1	0	0	0.1	0.2	0	0.1	0	0	0.1	0.0	0	0.1	0.2	0
III Tetracyclines	0	0	0	0	0	0.2	0	0.1	0	0.1	0	0	0	0	0	0
Total	**0.2**	**0.5**	**0.3**	**0.1**	**0.1**	**0.9**	**0.4**	**0.2**	**0.2**	**1.0**	**0.4**	**0.1**	**0**	**0.2**	**1.0**	**0.1**

Roman numerals I to III indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

DDDvetCA = Canadian Defined Daily Doses for animals (average labelled dose) in milligram per kilogram broiler weight per day (mg_{drug}/kg_{animal}/day); please refer to Appendix: Supplemental data, Table A. 1 for the list of standards.

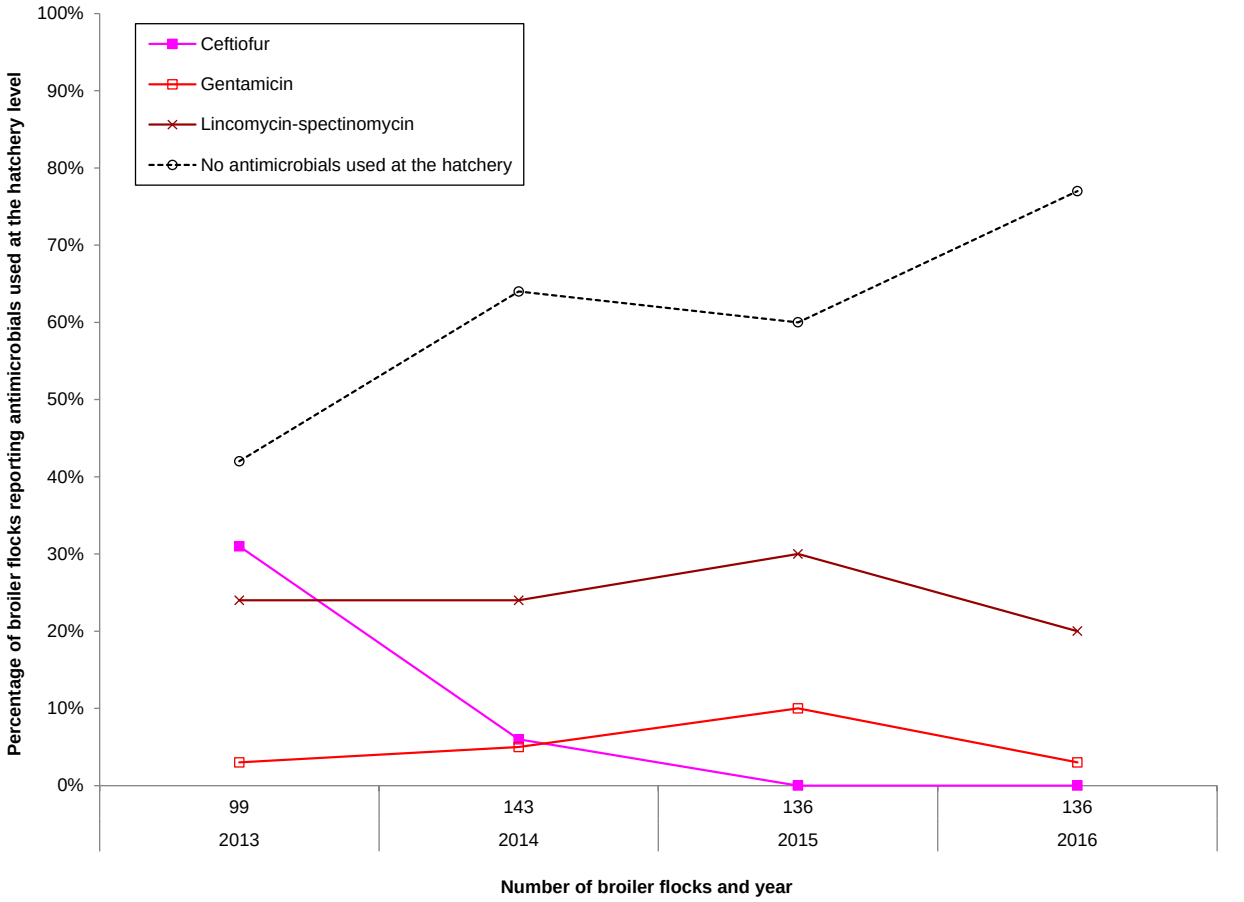
nDDDvetCA/PCU = number of DDDvetCA/population correction unit.

For detailed indicator description, please refer to Table 3. 1.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Antimicrobial use *in ovo* or subcutaneous injection by frequency

Figure 3. 26 Percentage of broiler flocks reporting antimicrobial use *in ovo* or subcutaneous injection at the hatchery level, 2013 to 2016



Year	2013	2014	2015	2016
Number of flocks	99	143	136	136
Antimicrobial				
I Ceftiofur	**31%**	6%	**0%**	**0%**
II Gentamicin	**3%**	5%	**10%**	**3%**
II Lincomycin-spectinomycin	**24%**	24%	**30%**	**20%**
No antimicrobials used at the hatchery	**42%**	64%	**60%**	**77%**

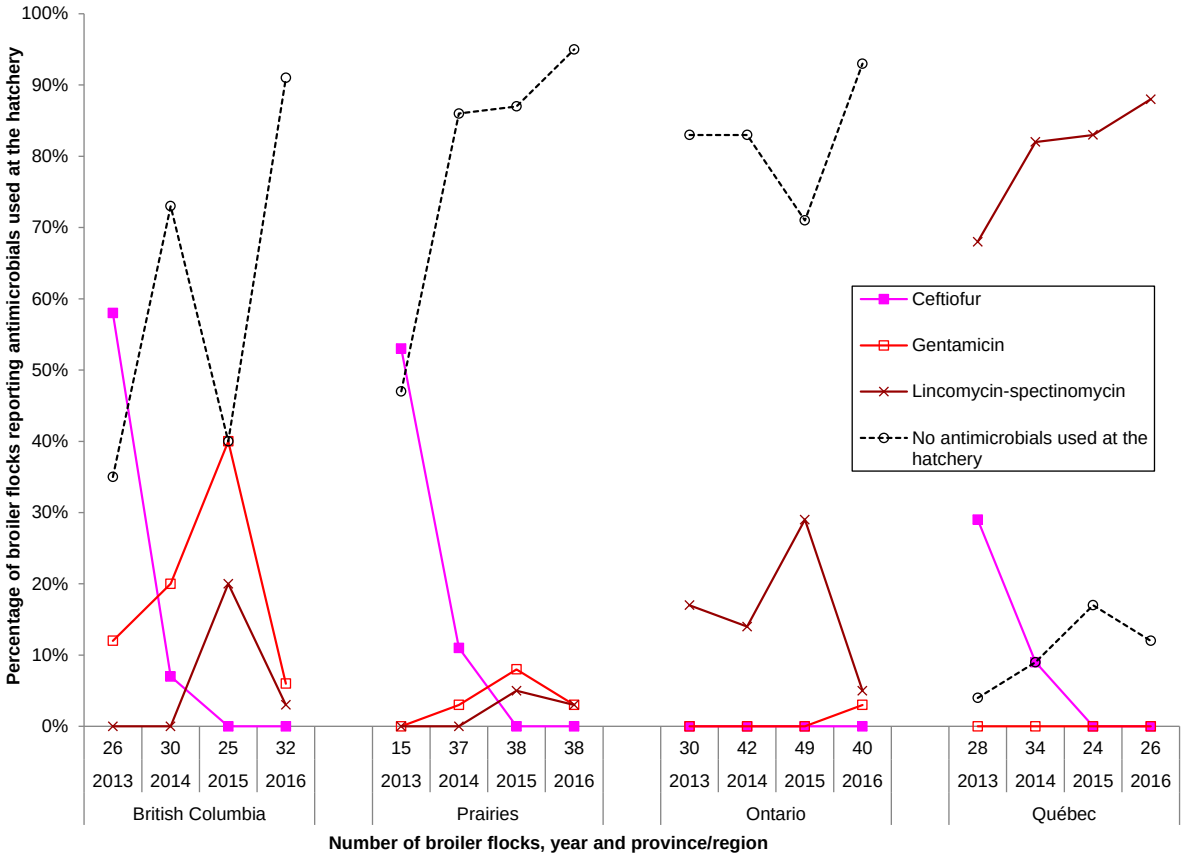
Roman numerals I to II indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

Numbers per column may not add up to 100% due to rounding and a batch of chicks (hatched at the same time to supply 1 barn) that may have used 2 antimicrobials.

Data represent flocks medicated at the hatchery at day 18 of incubation or upon hatch.

For the temporal analyses, the proportion (%) of flocks using a specific antimicrobial in the current year has been compared to the proportion (%) of flocks using the same antimicrobial in the first and previous surveillance year (grey areas). The presence of blue areas indicates significant temporal differences ($P \leq 0.05$) for a given antimicrobial

Figure 3. 27 Percentage of broiler flocks reporting antimicrobials used *in ovo* or subcutaneous injection at the hatchery level by province / region, 2013 to 2016



Province/region	British Columbia				Prairies				Ontario				Québec			
Year	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016
Number of flocks	26	30	25	32	15	37	38	38	30	42	49	40	28	34	24	26
Antimicrobial																
I Ceftiofur	58%	7%	0%	0%	53%	11%	0%	0%	0%	0%	0%	0%	29%	9%	0%	0%
II Gentamicin	12%	20%	40%	6%	0%	3%	8%	3%	0%	0%	0%	3%	0%	0%	0%	0%
II Lincomycin-spectinomycin	0%	0%	20%	3%	0%	0%	5%	3%	17%	14%	29%	5%	68%	82%	83%	88%
No antimicrobials used at the hatchery	35%	73%	40%	91%	47%	86%	87%	95%	83%	83%	71%	93%	4%	9%	17%	12%

Roman numerals I to II indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

Numbers per column may not add up to 100% due to rounding and a batch of chicks (hatched at the same time to supply 1 barn) that may have used 2 antimicrobials

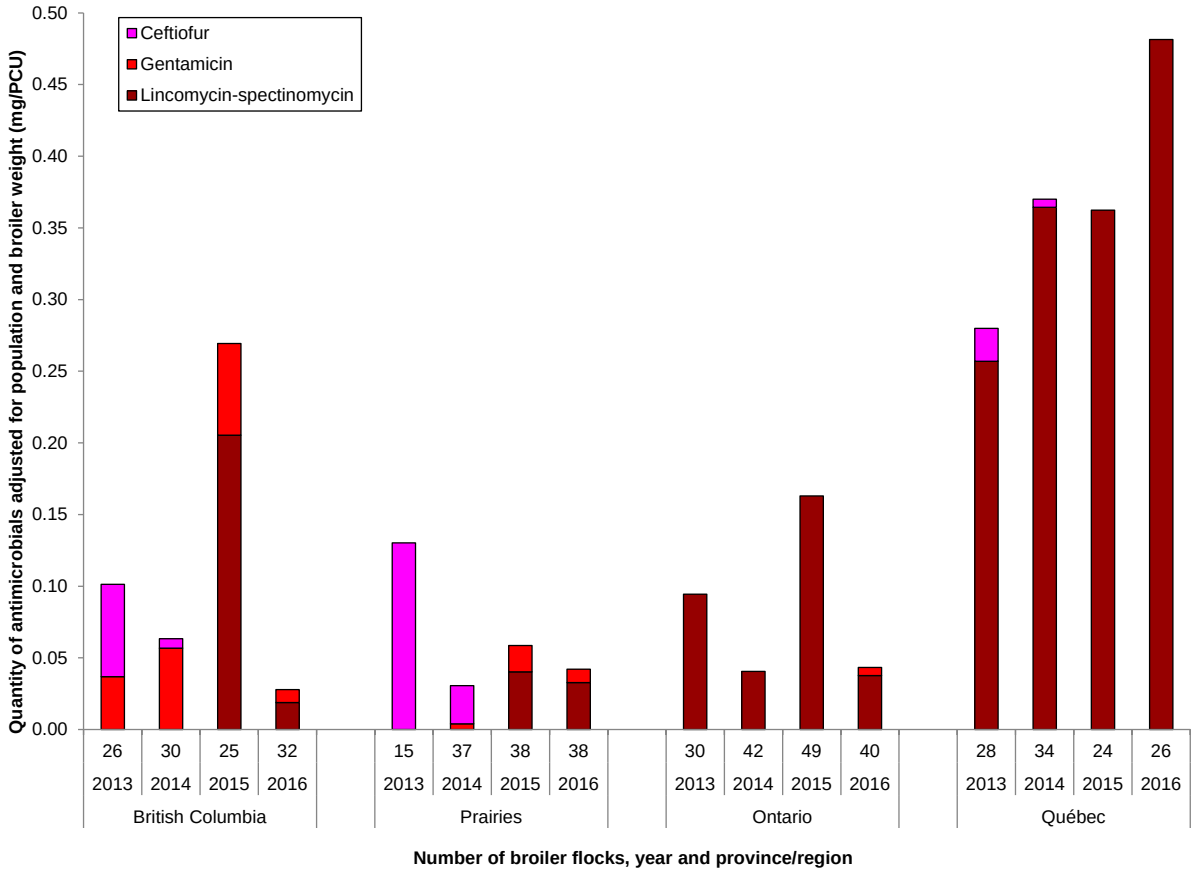
Data represent flocks medicated at the hatchery at day 18 of incubation or upon hatch.

For the temporal analyses, the proportion (%) of flocks using antimicrobial over the current year has been compared to the proportion (%) of flocks using the same antimicrobial during the first and the previous surveillance year (grey areas). The presence of blue areas indicate significant differences ($P \leq 0.05$) for a given province/region and antimicrobial. The presence of red areas indicates significant provincial/regional differences ($P \leq 0.05$) for a given antimicrobial within the current year. The presence of purple areas (2016 surveillance year; Québec-referent province) indicates significant temporal and provincial/regional differences ($P \leq 0.05$) for a given antimicrobial.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Antimicrobial use *in ovo* or subcutaneous injection by quantitative indicators

Figure 3. 28 Quantity of antimicrobial use *in ovo* or subcutaneous injections, adjusted for population and broiler weight (mg/PCU), 2013 to 2016



Province/region		British Columbia				Prairies				Ontario				Québec			
Year		2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016
Number of flocks		26	30	25	32	15	37	38	38	30	42	49	40	28	34	24	26
Antimicrobial																	
I	Ceftiofur	0.06	0.01	0	0	0.13	0.03	0	0	0	0	0	0	0.02	0.01	0	0
II	Gentamicin	0.04	0.06	0.06	0.01	0	0	0.02	0.01	0	0	0	0.01	0	0	0	0
	Lincomycin-spectinomycin	0	0	0.21	0.02	0	0	0.04	0.03	0.09	0.04	0.16	0.04	0.26	0.36	0.36	0.48
	Total	**0.10**	**0.1**	**0.27**	**0.03**	**0.13**	**0.03**	**0.06**	**0.04**	**0.09**	**0.04**	**0.16**	**0.04**	**0.28**	**0.37**	**0.36**	**0.48**

Roman numerals I to II indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

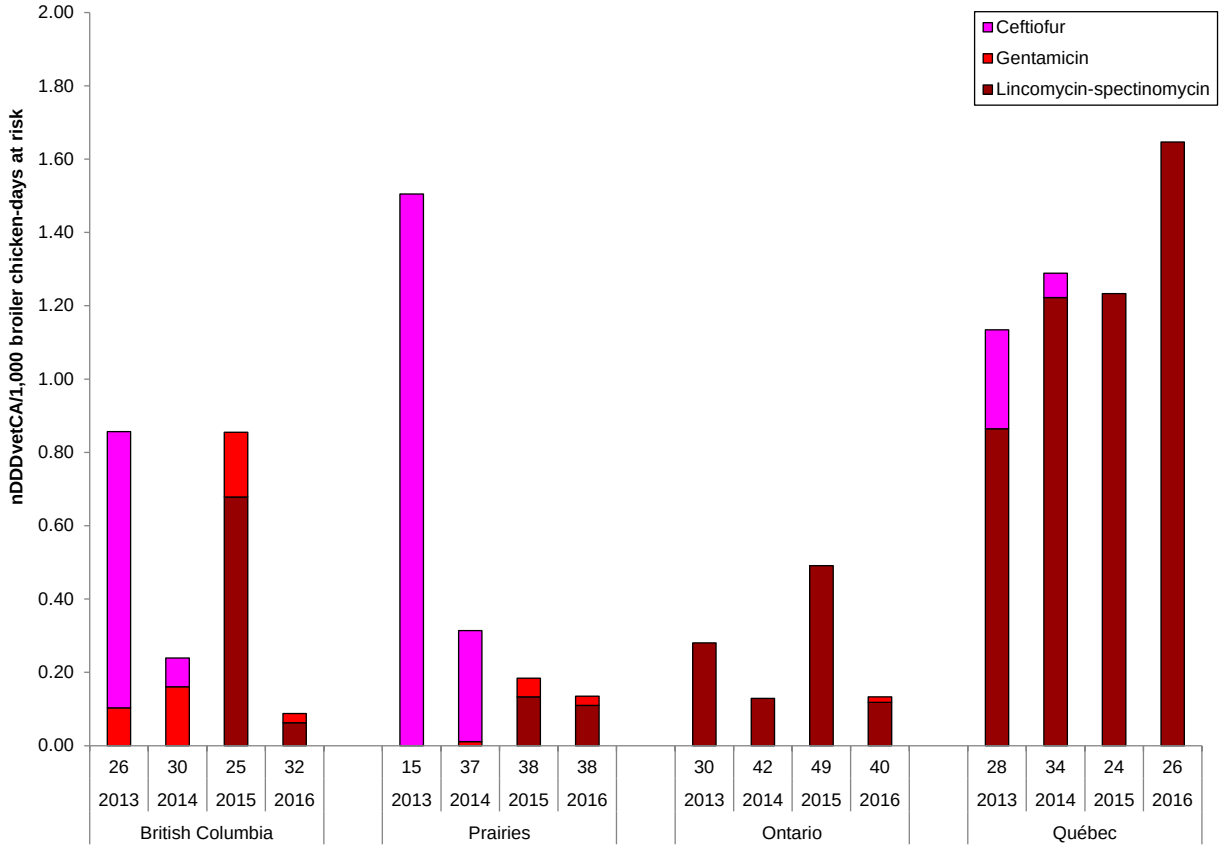
Total milligrams active ingredient was calculated using the final dose (in milligrams per hatching egg or chick) suggested by the manufacturer and expert opinion based on milligrams per body weight or residue avoidance information.

mg/PCU = milligrams/population correction unit.

For detailed indicator description, please refer to Table 3. 1.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Figure 3. 29 Number of Canadian Defined Daily Doses for animals per 1,000 broiler chicken-days at risk (nDDDvetCA / 1,000 broiler chicken-days at risk) for antimicrobials administered *in ovo* or subcutaneous injection, 2013 to 2016



Province/region		British Columbia				Prairies				Ontario				Québec			
Year		2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016
Number of flocks		24	29	25	32	15	37	38	38	30	42	49	40	28	33	23	26
Antimicrobial																	
I	Ceftiofur	0.75	0.08	0	0	1.50	0.30	0	0	0	0	0	0	0.27	0.07	0	0
II	Gentamicin	0.10	0.16	0.18	0.03	0	0.01	0.05	0.02	0	0	0	0.01	0	0	0	0
	Lincomycin-spectinomycin	0	0	0.68	0.06	0	0	0.13	0.11	0.28	0.13	0.49	0.12	0.86	1.22	1.23	1.65
	Total	**0.86**	**0.24**	**0.85**	**0.09**	**1.50**	**0.31**	**0.18**	**0.13**	**0.28**	**0.13**	**0.49**	**0.13**	**1.13**	**1.29**	**1.23**	**1.65**

Roman numerals I to II indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

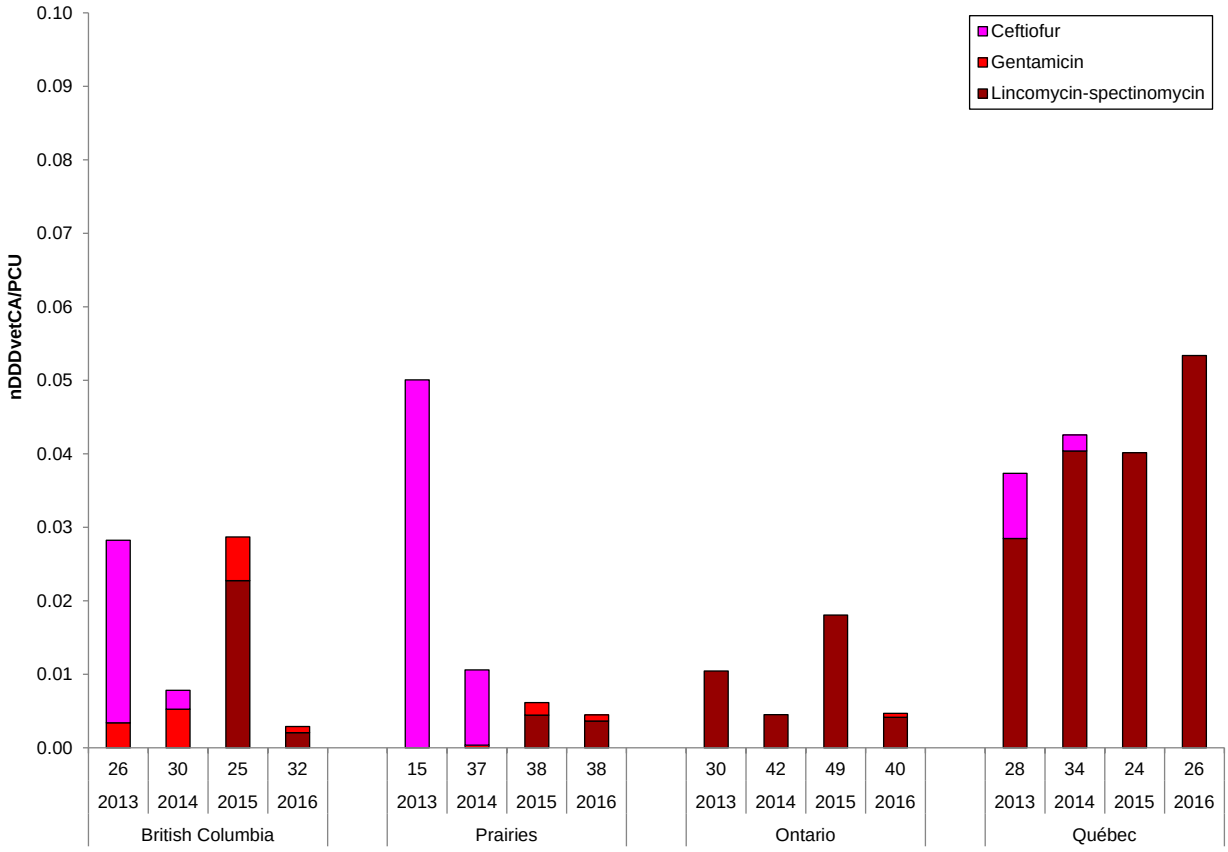
DDDvetCA = Canadian Defined Daily Doses for animals (average labelled dose) in milligram per kilogram broiler weight per day (mg_{drug}/kg_{animal}/day); please refer to Appendix: Supplemental data, Table A. 1 for the list of standards.

nDDDvetCA/1,000 broiler chicken-days at risk = number of DDDvetCA/1,000 broiler chicken-days at risk.

For detailed indicator description, please refer to Table 3. 1.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Figure 3. 30 Number of Canadian Defined Daily Doses for animals per population correction unit (nDDDvetCA/PCU) for antimicrobials administered *in ovo* or subcutaneous injection, 2013 to 2016



Province/region	British Columbia				Prairies				Ontario				Québec			
Year	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016
Number of flocks	24	29	25	32	15	37	38	38	30	42	49	40	28	33	23	26
Antimicrobial																
I Ceftiofur	0.02	0	0	0	0.05	0.01	0	0	0	0	0	0	0.01	0	0	0
II Gentamicin	0	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0
II Lincomycin-spectinomycin	0	0	0.02	0	0	0	0	0	0.01	0	0.02	0	0.03	0.04	0.04	0.05
Total	**0.03**	**0.01**	**0.03**	**0**	**0.05**	**0.01**	**0.01**	**0**	**0.01**	**0**	**0.02**	**0**	**0.04**	**0.04**	**0.04**	**0.05**

Roman numerals I to II indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

DDDvetCA = Canadian Defined Daily Doses for animals (average labelled dose) in milligram per kilogram broiler weight per day (mg_{drug}/kg_{animal}/day); please refer to Appendix: Supplemental data, Table A. 1 for the list of standards.

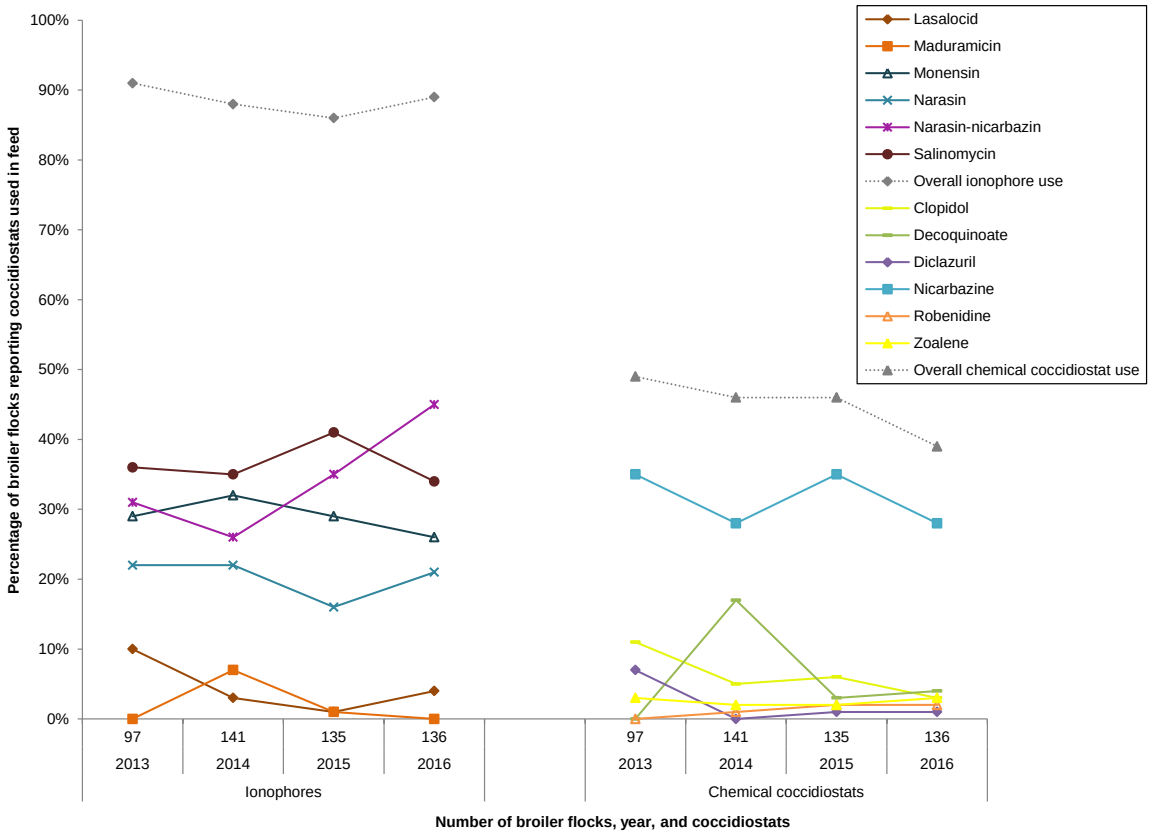
nDDDvetCA/PCU = number of DDDvetCA/population correction unit.

For detailed indicator description, please refer to Table 3. 1.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Coccidiostat use in feed by frequency

Figure 3. 31 Percentage of broiler flocks reporting coccidiostat use in feed, 2013 to 2016

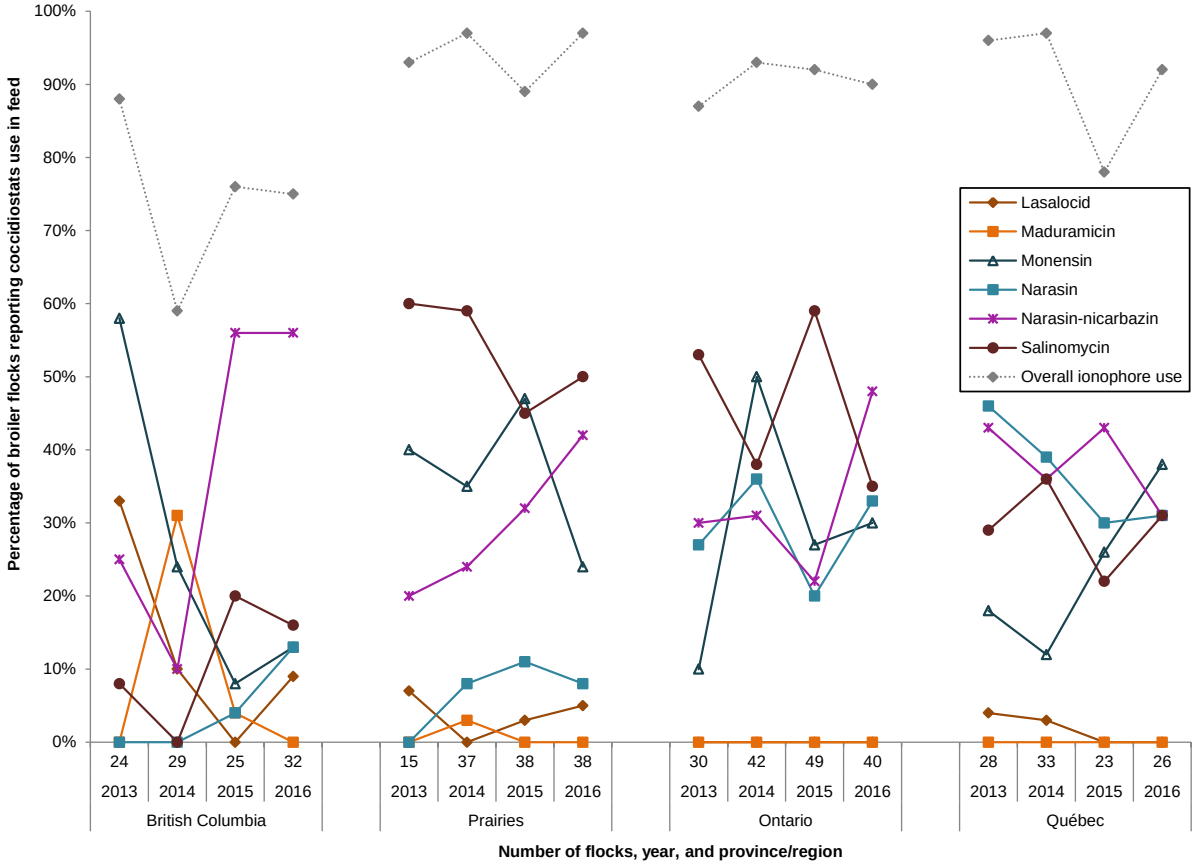


Year		2013	2014	2015	2016
Number of flocks		97	141	135	136
Coccidiostat					
IV	Lasalocid	**10%**	3%	**1%**	**4%**
IV	Maduramicin	**0%**	7%	**1%**	**0%**
IV	Monensin	**29%**	32%	**29%**	**26%**
IV	Narasin	**22%**	22%	**16%**	**21%**
IV	Narasin-nicarbazin	**31%**	26%	**35%**	**45%**
IV	Salinomycin	**36%**	35%	**41%**	**34%**
IV	**Overall ionophore use**	**91%**	88%	**86%**	**89%**
N/A	Clopidol	**11%**	5%	**6%**	**3%**
N/A	Decoquinoate	**0%**	17%	**3%**	**4%**
N/A	Diclazuril	**7%**	0%	**1%**	**1%**
N/A	Nicarbazine	**35%**	28%	**35%**	**28%**
N/A	Robenidine	**0%**	1%	**2%**	**2%**
N/A	Zoalene	**3%**	2%	**2%**	**3%**
N/A	**Overall chemical coccidiostat use**	**49%**	46%	**46%**	**39%**

Roman numeral IV indicates category of importance to human medicine as outlined by the Veterinary Drugs Directorate. N/A = not applicable (no classification at the time of writing of this report).

For the temporal analyses, the proportion (%) of flocks using a specific coccidiostat in the current year has been compared to the proportion (%) of flocks using the same coccidiostat in the first and the previous surveillance year (grey areas). The presence of blue areas indicates significant temporal differences ($P \leq 0.05$) for a given coccidiostat.

Figure 3. 32 Percentage of broiler flocks reporting ionophore coccidiostats in feed, by province / region, 2013 to 2016



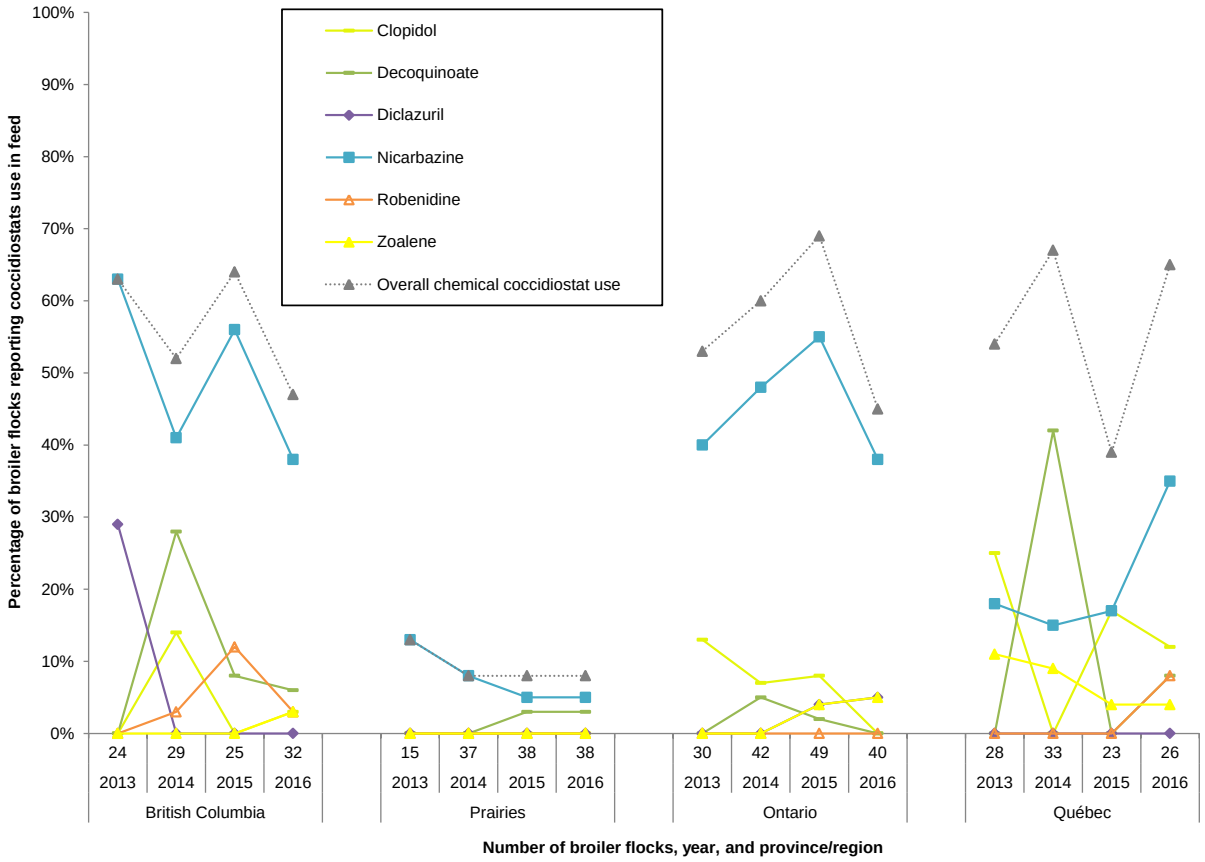
Province/region		British Columbia				Prairies				Ontario				Québec			
Year		2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016
Number of flocks		24	29	25	32	15	37	38	38	30	42	49	40	28	33	23	26
Coccidiostat																	
	Lasalocid	**33%**	10%	**0%**	**9%**	**7%**	0%	**3%**	**5%**	**0%**	0%	**0%**	**0%**	**4%**	3%	**0%**	**0%**
	Maduramicin	**0%**	31%	**4%**	**0%**	**0%**	3%	**0%**	**0%**	**0%**	0%	**0%**	**0%**	**0%**	0%	**0%**	**0%**
	Monensin	**58%**	24%	**8%**	**13%**	**40%**	35%	**47%**	**24%**	**10%**	50%	**27%**	**30%**	**18%**	12%	**26%**	**38%**
IV	Narasin	**0%**	0%	**4%**	**13%**	**0%**	8%	**11%**	**8%**	**27%**	36%	**20%**	**33%**	**46%**	39%	**30%**	**31%**
	Narasin-nicarbazin	**25%**	10%	**56%**	**56%**	**20%**	24%	**32%**	**42%**	**30%**	31%	**22%**	**48%**	**43%**	36%	**43%**	**31%**
	Salinomycin	**8%**	0%	**20%**	**16%**	**60%**	59%	**45%**	**50%**	**53%**	38%	**59%**	**35%**	**29%**	36%	**22%**	**31%**
	Overall ionophores use	**88%**	59%	**76%**	**75%**	**93%**	97%	**89%**	**97%**	**87%**	93%	**92%**	**90%**	**96%**	97%	**78%**	**92%**

Roman numeral IV indicates category of importance to human medicine as outlined by the Veterinary Drugs Directorate.

For the temporal analyses within province/region, the proportion (%) of flocks using a specific ionophore in the current year has been compared to the proportion (%) of flocks using the same ionophore in the first and the previous surveillance year (grey areas). The presence of blue areas indicates significant temporal differences within province/region ($P \leq 0.05$) for a given ionophore. The presence of red areas indicates significant provincial/regional differences ($P \leq 0.05$) for a given ionophore within the current year. The presence of purple areas (2016 surveillance year; Québec-referent province) indicates significant temporal and provincial/regional differences ($P \leq 0.05$) for a given ionophore.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Figure 3. 33 Percentage of broiler flocks reporting chemical coccidiostats in feed, by province / region, 2013 to 2016



Province/region		British Columbia				Prairies				Ontario				Québec			
Year		2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016
Number of flocks		24	29	25	32	15	37	38	38	30	42	49	40	28	33	23	26
Coccidiostat																	
N/A	Clopidol	**0%**	14%	**0%**	**3%**	**0%**	0%	**0%**	**0%**	**13%**	7%	**8%**	**0%**	**25%**	0%	**17%**	**12%**
	Decoquinoate	**0%**	28%	**8%**	**6%**	**0%**	0%	**3%**	**3%**	**0%**	5%	**2%**	**0%**	**0%**	42%	**0%**	**8%**
	Diclazuril	**29%**	0%	**0%**	**0%**	**0%**	0%	**0%**	**0%**	**0%**	0%	**4%**	**5%**	**0%**	0%	**0%**	**0%**
	Nicarbazine	**63%**	41%	**56%**	**38%**	**13%**	8%	**5%**	**5%**	**40%**	48%	**55%**	**38%**	**18%**	15%	**17%**	**35%**
	Robenidine	**0%**	3%	**12%**	**3%**	**0%**	0%	**0%**	**0%**	**0%**	0%	**0%**	**0%**	**0%**	0%	**0%**	**8%**
	Zoalene	**0%**	0%	**0%**	**3%**	**0%**	0%	**0%**	**0%**	**0%**	0%	**4%**	**5%**	**11%**	9%	**4%**	**4%**
	Overall chemical coccidiostat use	**63%**	52%	**64%**	**47%**	**13%**	8%	**8%**	**8%**	**53%**	60%	**69%**	**45%**	**54%**	67%	**39%**	**65%**

N/A = not applicable (no classification at the time of writing of this report).

For the temporal analyses within province/region, the proportion (%) of flocks using a specific chemical coccidiostat in the current year has been compared to the proportion (%) of flocks using the same chemical coccidiostat in the first and the previous surveillance year (grey areas). The presence of blue areas indicates significant temporal differences within province/region ($P \leq 0.05$) for a given chemical coccidiostat. The presence of red areas indicates significant provincial/regional differences ($P \leq 0.05$) for a given chemical coccidiostat within the current year. The presence of purple areas (2016 surveillance year; Québec-referent province) indicates significant temporal and provincial/regional differences ($P \leq 0.05$) for a given chemical coccidiostat.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Farm Surveillance in grower-finisher pigs

In 2016 the CIPARS Farm Surveillance component collected quantitative antimicrobial use (AMU) data for administrations through feed only, therefore the quantitative AMU data (weight and dose based estimates) presented in this section do not include quantitative data related to antimicrobials administered in water or by injection.

Key findings

Ninety-one grower-finisher pig herds participated in Farm Surveillance in 2016. Forty-four percent (40/91) of these herds were located in the Prairies (a region including the provinces of Alberta, Saskatchewan, and Manitoba), 30% (27/91) in Ontario and 26% (24/91) in Québec. Overall, 52% (47/91) of herds were All-In-All-Out operations and the remaining 48% (44/91) were continuous flow operations. The sample of herds in Québec and Ontario had more All-In-All-Out operations, 58% (14/24) and 56% (15.27), respectively, compared to those located in the Prairies where 45% (18/40) applied this management approach. The median number of pigs per grower-finisher period (pigs at risk) was 1,405 over all herds nationally. Prairie herds were the largest with a median of 2,097 pigs compared to 1,250 in Ontario and 1,102 in Québec. Nationally, there was a median number of 4 rations fed per grower-finisher period, which was the same number for Québec and Ontario herds, while the median number in Prairie herds was 5 rations fed per grower-finisher period.

Sixty-nine percent (63/91) of the participating herds reported using antimicrobials in feed (Table 3. 11), a 7% decrease (76%, 65/85) from 2015. Fifty-five percent of herds (50/91) reported administration by injection and 24% (22/91) through water, which is a 4% increase in the number of herds reporting AMU by these 2 routes of administration. Although 11% of herds (10/91) reported no AMU by any route of administration in 2016, similar to that reported in 2015 (12%, 10/85), the percentage of herds reporting no AMU in feed over the previous 5 years has increased to 31% (28/91) in 2016 from 18% (16/87) in 2012.

The most frequently reported antimicrobials used were penicillin G (43%, 39/91 herds) mostly administered by injection, lincomycin (38%, 35/91 herds) and tylosin (24%, 22/91 herds) mainly in feed, and chlortetracycline (24%, 22/91 herds) all in feed (Table 3. 12). Comparing 2016 to 2015, the number of herds reporting the use of penicillin G (43% in 2016 and 44% in 2015) and lincomycin (38% in 2016 and 39% in 2015) were similar. The use of tylosin decreased from 27% (23/85) in 2015 to 24% (22/91) in 2016, and the use of chlortetracycline also decreased from 35% (30/85) in 2015 to 24% (22/91) in 2016.

Administration in feed

Analyses of feed AMU in 2016 demonstrate that rankings and trends changed depending on the indicator used to quantify particular antimicrobial uses. For example, in assessing AMU frequencies (herd counts) in 2016 the highest ranking use in feed was lincomycin at 27% (25/91 herds) followed by chlortetracycline at 22% (24/91), and tylosin 18% (20/91). However, this ranking changes when comparing weight based measures of AMU, expressed as milligrams of use adjusted for population and weight (mg/PCU), with the largest quantity used in feed being 51 mg/PCU for chlortetracycline, followed by 28 mg/PCU for lincomycin then 26 mg/PCU for tylosin (Table 3. 13).When applying dose based measures of AMU, the number of Defined Daily Doses (nDDDvetCA) expressed as the an incidence rate of AMU by using an animal-time denominator (1,000 PDAR = 1,000 pig-days at risk), tylosin emerges as the largest quantity of use at 75 nDDDvetCA/1,000 PDAR followed by lincomycin at 49 nDDDvetCA/1,000 PDAR and chlortetracycline at 43 nDDDvetCA/1,000 PDAR.

The proportion of rations medicated and the duration of AMU (exposure) in feed are 2 indicators of AMU that are important to industry given their immediate applicability to the farm setting. Over all rations reported through herd questionnaires, 59% were medicated in 2016 (Table 3. 13). Fifty-seven percent of rations were medicated with lincomycin, 38% with tylosin, and 27% with chlortetracycline. The duration of exposure was shorter for chlortetracycline at 21 days compared to 28 days, the median duration share by lincomycin and tylosin.

The proportion of rations medicated was generally lowest in Ontario compared to Québec and the Prairies over 2012 to 2015, but in 2016 the proportion of medicated rations declined in the Prairies and Québec below that in Ontario (Table 3. 14).

At a national level, a significant decrease in the frequency of tylosin use in feed was noted between 2009 (41%, 39/95 herds) and 2016 (20%, 18/91 herds) (Figure 3. 34), which appears to be due to a decrease in tylosin use across all provinces/regions (Figure 3. 35). In 2016, there was a significant decrease in the number of Québec herds reporting the use of chlortetracycline (25%, 6/24) compared to 2015 (57%, 12/21) and 2012 (65%, 13/20).

Estimates of the total quantity of AMU in feed, using weight based indicators adjusted for population and pig weight, declined across all regions in 2016 relative to 2015 to a national low of 115 mg/PCU (Figure 3. 36). Except for 2015, there has been a downward trend in the total quantity of antimicrobial use in feed in Québec since 2012. The apparent increase in AMU in Ontario and Québec during 2014 to 2015 may have been related to different disease pressures across regions, e.g., the emergence of Porcine Epidemic Diarrhea (PED).

The decrease in the total use in feed was due largely to a drop in the use of tetracyclines (52 mg/PCU in 2016 compared to 97 in 2015), and a lower use of streptogramins (0.4 mg/PCU in 2016 compared to 9.0 in 2015) and pleuromutilins (1.9 mg/PCU in 2016 compared to 4.7 in 2015) (Figure 3. 36). Regionally, there were decreases in the use of tetracyclines in feed across all 3 regions, most notably in the Prairies (Figure 3. 37). The sharp decline in the quantity of streptogramin use was due to a drop in use in Ontario herds from 38 mg/PCU in 2015 to 2 mg/PCU in 2016; Prairie and Québec herds did not report any streptogramin use in feed in 2015. In Québec, the use of macrolides (tylosin) in feed varied between 31 and 37 mg/PCU over 2012 to 2015, and in 2016 this use in feed dropped to 5 mg/PCU, but the reported use of lincosamides in feed increased in 2016 to 35 compared to 13 mg/PCU in 2015.

When adjusting for differences in dosage among antimicrobials used in feed by applying dose based indicators, nDDDvetCA/1,000 PDAR or nDDDvetCA/PCU, the rank order shifts compared to rankings from weight based estimates, mg/PCU. In 2016 the top 5 antimicrobials (from highest to lowest) used in feed, estimated as mg/PCU, were:

- tetracyclines
- lincosamides
- macrolides
- sulfonamides
- penicillins

When the quantities of AMU in feed were estimated using dose based indicators, the rank order changed to (Figure 3. 38 and Figure 3. 40):

- macrolides
- lincosamides
- tetracyclines
- penicillins
- sulfonamides

At a national level (all participating herds), the temporal trends in dose based indicators of AMU also show decrease in the total number of doses administered in feed in 2016 (195 nDDDvetCA/1,000 PDAR) compared to the range in this indicator over 2009 to 2015 (251 to 280 nDDDvetCA/1,000 PDAR). This was due largely to decreases in tetracycline (mainly chlortetracycline) and streptogramin (virginiamycin) use in 2016 compared to 2015, 44 from 82 nDDDvetCA/1,000 PDAR and 1 from 24 nDDDvetCA/1,000 PDAR, respectively (Figure 3. 38). All of the streptogramin use in 2015 (100 nDDDvetCA/1,000 PDAR) was reported from farms in Ontario, down to 4 nDDDvetCA/1,000 PDAR in 2016, which contributed greatly to the overall decrease in the number of doses administered in that province, down to 196 from 322 nDDDvetCA/1,000 PDAR (Figure 3. 39). Québec reported the lowest total number of doses administered in feed among the 3 regions in 2016, 165 nDDDvetCA/1,000 PDAR, down from 268 in 2015. This was achieved primarily through decreases in the number of macrolide doses administered, down to 13 nDDDvetCA/1,000 PDAR in 2016 from 67 in 2015, while the number of doses of macrolides used increased in the Prairies and Ontario. Declines in the number of aminoglycoside (0 nDDDvetCA/1,000 PDAR in 2016, 23 in 2015) and tetracycline (89 nDDDvetCA/1,000 PDAR in 2016, 137 in 2015) doses used in feed also contributed to the overall decline in Québec. The overall decrease in the number of doses reported by Prairie farms (206 nDDDvetCA/1,000 PDAR in 2016, 258 in 2015) came mainly from declines in lincosamide (52 nDDDvetCA/1,000 PDAR in 2016, 77 in 2015) and tetracycline (23 nDDDvetCA/1,000 PDAR in 2016, 63 in 2015) administrations in feed.

The trends in dose based estimates adjusted for pig population and weight nDDDvetCA/PCU (Figure 3. 40 and Figure 3. 41) are correlated with those described above for nDDDvetCA/1,000 PDAR estimates of AMU in feed.

By any unit of measure, frequency, weight or dose based, trends indicate a decline in antimicrobial use in grower-finisher swine feed in 2016 compared to previous years.

The application of multiple indicators provides policy makers with a comprehensive understanding of AMU in a given sector, which will help prioritize interventions that will have the most immediate impact on improving antimicrobial stewardship.

Note: Findings regarding reasons for AMU in feed are not depicted in tables or figures, but are described in the following text.

Excluding ionophores, in 2016 the proportions of rations used for disease prevention was 74% (117/159), for growth promotion 21% (34/159) and for disease treatment 5% (8/159). Compared to the previous 4 years, where the proportions of all rations for 2012 to 2015 were 57% (470/823), 31% (259/8230) and 11% (94/823), respectively, there was an increase in the proportion of rations medicated for disease prevention and a decrease in the proportion used for growth promotion and disease treatment. In assessing temporal trends (2012 to 2016) by region, Prairie herds reported a significantly higher proportion of rations medicated for disease prevention in 2016 (64%, 55/86) compared to 2015 (48%, 42/87) and 2012 (37%, 42/113). Also in Prairie herds, there were significant decreases in the number of rations reportedly medicated for growth promotion (29%, 25/86) and disease treatment (7%, 6/86) in 2016 compared to 2012, where 46% (52/113) of rations were medicated for growth promotion and 17% (19/113) for disease treatment. Similar trends were noted in Ontario and Québec herds but the differences in the proportions of rations were not significantly different. In 2016, Ontario herds reported that 92% (44/48) of medicated rations were administered for disease prevention, which was higher compared to Prairie herds (64%, 55/86) and significantly higher compared to Québec herds (72%, 18/25).

Comparing weight-based indicators (mg/PCU), the quantity of AMU for disease prevention increased to 66% (77/116 mg/PCU) of the total amount used in 2016 compared to 51% (90/176 mg/PCU) in 2015. The amount of AMU for growth promotion decreased from 40% (70/176 mg/PCU) of the total quantity in 2015 to 30% (35/116 mg/PCU) in 2016, and similarly, the amount used for disease treatment decreased from 9% (16/176 mg/PCU) in 2015 to 3% (4/116 mg/PCU) in 2016.

Excluding ionophores, the top 3 antimicrobials used in feed for disease prevention in 2016 included lincomycin (39%, 46/117), tylosin (24%, 28/117), and chlortetracycline (20%, 23/117). For disease treatment, the pleuromutilin antimicrobial tiamulin, made up 50% (4/8) of the low level of reported disease treatment use in feed followed by lincomycin at 38% (3/8) and chlortetracycline at 13% (1/8). Tylosin (29%, 10/34) and lincomycin (24%, 8/34) accounted for 53% (18/34) of the rations medicated for growth promotion, when excluding ionophores. The majority of the reported use of chlortetracycline (85%, 23/27) and lincomycin (81%, 46/57) was for disease prevention, followed by 11% (3/27) and 14% (8/57) of rations, respectively, which were used for growth promotion, and the remainder for disease treatment. Similarly, the rations medicated with tylosin in 2016 were mainly used for disease prevention (74%, 28/38) and growth promotion (26%, 10/38), with no use in feed for disease treatment.

Of the secondary reasons under “Disease treatment” and “Disease prevention”, 65% (84/129) of the rations were medicated for the prevention of enteric and/or respiratory disease in 2016. Nineteen percent (25/129) were for the prevention of lameness and/or enteric and respiratory disease. Nine percent (12/129) of ration indicated “Other” secondary reasons for use, specified as mainly for the treatment of *Streptococcus suis* (60%, 6/10) and/or *Actinobacillus suis* (40%, 4/10), for which chlortetracycline, penicillin, and sulfamethazine were used in the same proportion; two rations did not specify an “Other” reason for use.

Administration in water

Penicillin continued to be the antimicrobial most frequently administered in water, ranging from to 21% (19/95) of herds reporting its use in 2009 down to 12% (11/91) of herds in 2016 (Figure 3. 42). The proportion of herds reporting no use of antimicrobials in water remained generally unchanged in 2016 (79%, 72/91) compared to 2015 (81%, 69/85).

In 2016 the proportion of herds reporting no use of antimicrobials in water in grower-finisher herds was significantly higher in the Prairies (88%, 35/40) and Ontario (93%, 25/27) compared to that reported in Québec herds (50%, 12/24) (Figure 3. 43). Penicillin was the most frequently report AMU in water in the Prairies (13%, 5/40) and Ontario (7%, 2/27), while in Québec the most frequently reported antimicrobial used in water was trimethoprim-sulfadoxine (25%,6/24), exceeding the use of penicillin (8%, 2/24) in 2016. Lincomycin use in water was only reported in Québec herds.

Since 2009 the frequency of AMU in water reported for disease treatment has doubled from 29% (10/34) to 60% (25/42) in 2016. The balance of AMU in water was for disease prevention which has declined from 71% (24/34) to 40% (17/42) over the same period. The specified reasons for use in 2016 where primarily for the treatment (48%, 20/42) and prevention (33%, 14/42) of respiratory disease followed by the treatment (12%, 5/42) and prevention (5%, 2/42)of gastrointestinal disease, and the treatment (12%, 5/42) and prevention (2%, 1/42) of lameness. There was only one (2%, 1/42) antimicrobial use in water for the treatment of “Other” reasons, which was specified as a treatment for *S. suis* with penicillin. Of the total specified “Other” reasons for use over 2009 to 2016, the top 3 reasons for use were for the treatment or prevention of *S. suis* (51%, 19/37), Erysipelas (19%, 7/37) or *A. suis* (11%, 4/37), typically using penicillin or streptomycin.

Over 2009 to 2016 Prairie herds reported a greater number of water administrations for disease prevention (70%, 70/100) compared to those in Ontario (36%, 21/38) and Québec (25%, 36/143). In 2016, the proportion of herds reporting water AMU for disease treatment was 57% (4/7) in Ontario and 95% (20/21) in Québec, while Prairie herds reported that only 7% (1/14) of water AMU was for disease treatment.

Over 2009 to 2016, the antimicrobials that made up the majority of water AMU in Prairie herds were penicillin for disease prevention (33%, 33/100) and treatment (11%, 11/100), and streptomycin (14%, 14/100) and tetracycline (9%, 9/100) for disease prevention. In Ontario the most common antimicrobial uses in water were penicillin for disease treatment (24%, 14/59) and prevention (14%, 8/59), and streptomycin for disease treatment (15%, 9/59). In Québec the most commonly used antimicrobials were trimethoprim-sulfadoxine for disease treatment (20%, 29/143), and penicillin for disease treatment (17%, 25/143) and prevention (10%, 15, 143).

The proportion of the herds exposed to antimicrobials in water remains mainly within the range of 76% to 100% of pigs. Interestingly, the number of herds reporting 76% to 100% pig exposure has declined from 86 % (30/35) of herds in 2009 to 71% (30/42) in 2016, with moderate increases in the lower herd exposure quartiles; in 2016 there was 7% (3/42) of herds reporting 1 to 25% pigs exposed, 12% (5/42) reporting 26 to 50%, and 10% (4/42) reporting 51 to 75%. This suggests that AMU in water is becoming more targeted (vs. mass treatment of the entire herd), a trend that could contribute to better antimicrobial stewardship.

Administration by injection

Over the 8 year period of 2009 to 2016 the antimicrobial most frequently reported for use by injection was penicillin; 31% of herds (28/91) reported using penicillin by injection, but its use has been in decline since 2013, when 53% of herds (47/89) reported this AMU (Figure 3. 44). Another β-lactam antimicrobial, the 3rd generation cephalosporin ceftiofur, was the only Category I (Very High Importance in human medicine) reported for use in grower-finisher pigs and was the second most frequently reported administration by injection in 2016 (22%, 20/91 herds). The use of florfenicol by injection continued to be reported by a relatively low number of herds, declining somewhat since 2014 (13%, 12/95), but the number of herds reporting this use remains significantly higher in 2016 (8%, 7/91) compared to that in 2009 (1%, 1/95).

In certain instances of AMU by injection, the temporal and regional variation in the frequency of use of different antimicrobials is noteworthy. In 2016, the Prairies had the highest proportion of herds (53%, 21/40) reporting no AMU by injection compared to Ontario (41%, 11/27) and Québec (38%, 9/24) (Figure 3. 45). In Ontario, the frequency of reported use of penicillin by injection dropped significantly in 2016 (33%, 9/27) compared to 2012 (70%, 19/27). The reported use of ceftiofur increased to 28% (11/40) in the Prairies and was stable in Québec (33%, 8/24), while in Ontario its use remains relatively infrequent (4%, 1/27). The use of florfenicol by injection appears to be primarily in Québec herds, where the frequency of reported the use (25%, 6/24) was significantly higher in 2016 compared to Prairie herds where there was no reported use; only one herd in Ontario reported using florfenicol by injection in 2016, (1%, 1/27). The proportion of Ontario herds reporting oxytetracycline use by injection (26%, 7/27) was significantly higher than that reported by Prairie herds (5%, 2/40); no Québec herds reported treating pigs with oxytetracycline injections.

Since 2009, three quarters of the antimicrobial administrations by injection were reported to be for the treatment of lameness alone (34%, 284/832), for the treatment of respiratory disease alone (27%, 224/832), or for the treatment of both lameness and respiratory disease (14%, 117/832). In 2016 the proportion of antimicrobial administrations by injection to treat lameness increased to 50% (51/102), while treatments for respiratory disease alone, and both lameness and respiratory disease declined in frequency to 20% (20/102) and 9% (9/102), respectively. In the vast majority of all administrations by injection (93%, 775/832) 5% of the pigs or less in the herd were treated; of the remaining administrations, the reported range of pigs treated was in the “6 to 25%” range. In 2016, while the majority of treatments by injection were also administered to 5% of the pigs or less (88%, 90/102), there appeared to be small increases in the number of administrations in the “6 to 25%” (8%, 8/102) and “26 to 50%” (4%, 4/102) ranges of pigs treated. This small increase in the number of pigs exposed to injectable treatments is due to regional differences: in Ontario all AMU by injection were administered to 5% of the pigs or less ; in Québec, 7 treatments by injection (7%, 7/102) were administered to “6 to 25 %” of the pigs, and in Prairie herds there were 4 treatments by injection (4%, 4/102) given to “26 to 50%” of the pigs and 1 treatment (1%, 1/102) given to “6 to 25%” of the pigs, all to treat lameness and/or respiratory disease. Again, although the numbers are low, this may be indicative of a more targeted approach to the therapeutic use of antimicrobials and improved stewardship.

Considering all administrations by injection, 2009 to 2016, the reported antimicrobials used to treat lameness cases were mainly penicillin (53%, 151/284), ceftiofur (15%, 43/284) and lincomycin (12%, 34/284). In cases of respiratory disease the most frequently reported injectable treatments were tulathromycin (27%, 60/223) followed by ceftiofur (19%,

43/223), florfenicol (14%, 32/223) and penicillin (14%, 32/223). When the reported reasons for AMU were to treat both lameness and respiratory disease, penicillin (48%, 56/117) and ceftiofur (26%, 30/117) were the most frequently used injectable treatments. Although relatively infrequent (7%, 55/831), AMU by injection to treat gastrointestinal disease in grower-finisher pigs included mainly tylosin (47%, 26/55), oxytetracycline (15%, 8/55) and ceftiofur (13%, 7/55). As expected, there were differences in the antimicrobial injections used among the 3 regions. In 2016, Ontario was the only region where herds reported the use of enrofloxacin to treat lameness (3%, 1/29) and respiratory disease (7%, 2/29), whereas Prairie and Québec herds reported more use of ceftiofur, 26% (11/42) and 26% (8/31), respectively, compared to Ontario (3%, 1/29), to treat lameness and/or respiratory and/or gastrointestinal disease.

In 2016, the specified “Other” reasons for AMU by injection included tail bites, wounds and *S. suis* infections, with either penicillin, oxytetracycline, ceftiofur, lincomycin or trimethoprim-sulfadoxine.

Ionophores and chemical coccidiostats

Data from the herd questionnaires identified the use of 2 ionophore coccidiostats in feed. More herds reported salinomycin use in feed relative to the low frequency use of narasin. The first reports of narasin use in feed emerged in 2015. Ionophores were reported as being fed for a third to half of the grow-finish period, and typically 100% of the pigs were exposed (Table 3. 15). Comparing their frequency of use over the years 2009 to 2016 and all herds in our surveillance program nationally, 23% (21/91) reported the use of salinomycin in 2016, which is a 9% increase from 2009 (14%, 13/95), and 3% (3/91) of herds reported the use of narasin (Figure 3. 46).

There were notable regional differences in ionophore use in feed (Figure 3. 47). The proportion of herds reporting salinomycin and narasin use in feed was generally highest in Québec, where there were increasing trends in the number of herds reporting the use of salinomycin (2012: 35%, 7/20; 2016: 50%, 12/24) and a minor increase in narasin use (2015: 5%, 1/21; 2016: 8%, 2/24). In Ontario, the proportion of herds reporting salinomycin use has increased from 4% (1/27) in 2012 to 15% in 2016 (4/27); there was no reported use of narasin in Ontario. The proportion of Prairie herds reporting salinomycin use declined to 13% (5/40) in 2016 from 23% (9/40) in 2012, and only 1 herd reporting the use of narasin in both 2015 and 2016.

In 2016, the reasons for ionophore use in feed were generally reported as being either for growth promotion (84%, 66/79) or for the prevention of enteric disease (16%, 13/79).

Summary of antimicrobial use by route of administration

Table 3. 11 Number of grower-finisher pig herds with reported antimicrobial use by route of administration, 2016

Antimicrobial use	Route of administration			
	Any route[a] n (%)	Feed n (%)	Water n (%)	Injection n (%)
Any antimicrobial use	81 (89)	63 (69)	22 (24)	50 (55)
No antimicrobial use	10 (11)	28 (31)	69 (76)	41 (45)
Total herds	**91 (100)**	**91 (100)**	**91 (100)**	**91 (100)**

[a] Herds with reported use of an antimicrobial class by feed, water, injection, or any combination of these routes are included in each count

Table 3. 12 Number of grower-finisher pigs with reported use of specific active antimicrobial ingredients by route of administration, 2016 (n = 91 herds)

Antimicrobial class		Antimicrobial	Route of administration			
			Any route[a] n (%)	Feed n (%)	Water n (%)	Injection n (%)
I	Extended-spectrum cephalosporins	Ceftiofur	20 (22)	0 (0)	0 (0)	20 (22)
II	Aminoglycosides	Streptomycin	3 (3)	0 (0)	3 (3)	0 (0)
	Lincosamides	Lincomycin	35 (38)	25 (27)	2 (2)	11 (12)
	Macrolides	Erythromycin	0 (0)	0 (0)	0 (0)	0 (0)
		Tilmicosin	0 (0)	0 (0)	0 (0)	0 (0)
		Tulathromycin	9 (10)	0 (0)	0 (0)	9 (10)
		Tylosin	22 (24)	18 (20)	0 (0)	4 (4)
		Tylvalosin	1 (1)	1 (1)	0 (0)	0 (0)
	Penicillins	Ampicillin	5 (5)	0 (0)	0 (0)	5 (5)
		Penicillin G	39 (43)	8 (9)	11 (12)	28 (31)
	Combination of sulfadoxine and trimethoprime	Trimethoprim-sulfadoxine	10 (11)	0 (0)	6 (7)	5 (5)
	Streptogramins	Virginiamycin	1 (1)	1 (1)	0 (0)	0 (0)
III	Aminocyclotols	Spectinomycin	0 (0)	0 (0)	0 (0)	0 (0)
	Aminoglycosides	Neomycin	2 (2)	0 (0)	2 (2)	0 (0)
	Bacitracins	Bacitracin	0 (0)	0 (0)	0 (0)	0 (0)
	Phenicols	Florfenicol	7 (8)	0 (0)	0 (0)	7 (8)
	Pleuromutilins[b]	Tiamulin	7 (8)	6 (7)	0 (0)	1 (1)
	Sulfonamides	Sulfonamide (unspecified)	8 (9)	5 (5)	3 (3)	0 (0)
	Tetracyclines	Chlortetracycline	22 (24)	22 (24)	0 (0)	0 (0)
		Oxytetracycline	10 (11)	1 (1)	6 (7)	9 (10)
		Tetracycline	0 (0)	0 (0)	0 (0)	0 (0)
IV	Flavophospholipids	Bambermycin	4 (4)	4 (4)	0 (0)	0 (0)

Roman numerals I to IV indicate the ranking of antimicrobials based on importance to human medicine as outlined by the Veterinary Drugs Directorate.

[a] Herds with reported use of an antimicrobial class by feed, water, injection, or any combination of these routes are included in each count.

[b] Pleuromutilins are not officially categorized in the current Health Canada Classification System. However, according to the criteria provided by Health Canada, pleuromutilins meet the criteria for Category III.

Table 3. 13 Frequency and quantity of antimicrobial use in grower-finisher pigs, 2016

Route of administration	Antimicrobial	Herds n (%) Total n = 91	Rations n (%) *Total n = 400	Ration days exposed[a] median (min. ; max.)	Percent of herd exposed median (min. ; max.)	Weight at exposure median[b] (min. ; max.)[c]	Level of drug g/tonne[d] median (min. ; max.)	Quantity of antimicrobial active ingredient[e]		
								mg/PCU	nDDDvetCA / 1,000 GF pig-days at risk	nDDDvetCA / PCU
Feed										
II	Lincomycin	25 (27)	57 (24)	28 (5 ; 70)	100 (40 ; 100)	70 (20 ; 135)	44 (44 ; 110)	28	49	6
	Penicillin	8 (9)	10 (4)	21 (2 ; 35)	100 (25 ; 100)	38 (23 ; 65)	82 (55 ; 312)	3	12	1
	Tylosin	18 (20)	38 (16)	28 (3 ; 70)	100 (50 ; 100)	69 (27 ; 145)	44 (20 ; 200)	26	75	9
	Tylvalosin	1 (1)	1 (0)	21 (21 ; 21)	100 (100 ; 100)	42 (32 ; 52)	42 (42 ; 42)	0.6	2.9	0.3
	Virginiamycin	1 (1)	4 (2)	28 (28 ; 28)	100 (100 ; 100)	75 (25 ; 125)	11 (11 ; 11)	0.4	1.1	0.1
III	Chlortetracycline	22 (24)	27 (11)	21 (2 ; 42)	100 (25 ; 100)	38 (23 ; 93)	440 (110 ; 1,210)	51	43	5
	Oxytetracylcine	1 (1)	1 (0)	21 (21 ; 21)	100 (100 ; 100)	35 (25 ; 45)	550 (550 ; 550)	0	0	0
	Sulfamethazine	5 (5)	6 (3)	15 (2 ; 35)	100 (25 ; 100)	41 (23 ; 58)	110 (110 ; 625)	3	7	1
	Tiamulin	6 (7)	7 (3)	10 (6 ; 42)	100 (100 ; 100)	40 (20 ; 90)	50 (31 ; 200)	2	4	0
IV	Bambermycin	4 (4)	8 (3)	35 (14 ; 70)	100 (100 ; 100)	59 (25 ; 125)	3 (2 ; 4)	0.2		
No AMU in feed		28 (31)	164 (41)	28 (4 ; 133)	100 (50 ; 100)	77 (20 ; 140)				
Total for medicated feed		**53 (58)**	**238 (59)**	**28 (2 ; 84)**	**100 (25 ; 100)**	**53 (20 ; 145)**		**116**	**195**	**22**

Roman numerals I to IV indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

Grey shaded cells = no data or calculations/values are not applicable for grower-finisher pigs.

mg/PCU = milligrams/population correction unit.

DDDvetCA = Canadian Defined Daily Doses (average labelled dose) in milligrams per kilogram grower-finisher pig weight per day (mg_{drug}/kg_{animal}/day); please refer to Appendix: Supplemental data, Table A. 2 for the list of standards.

nDDDvetCA/1,000 GF pig-days at risk = number of DDDvetCA/1,000 grower-finisher pig-days at risk.

nDDDvetCA/PCU = number of DDDvetCA/population correction unit.

For detailed metric description, please refer to Table 3. 1.

[a] Ration days exposed = for rations medicated with the specific antimicrobial and do not reflect the full grow-out period.

[b] Median weight at exposure = the median of all average weights of pigs exposed to a ration containing a specific antimicrobial [(Ration Start Weight + Ration End Weight)/2].

[c] Minimum (min.) and maximum (max.) pig weight at exposure = the lowest start weight and the highest end weight reported for all rations containing the specific antimicrobial, respectively.

[d] Level of drug is in grams/tonne of feed.

[e] Quantitative antimicrobial consumption estimates were calculated using reported ration days fed and predicted feed intake[60], adjusted for herd average daily gain; only rations medicated with the specific antimicrobial were included in this analysis; the final mg/PCU, nDDDvetCA/1,000 broiler chicken-days at risk and nDDDvetCA/PCU exclude coccidiostats and pyrimethamine. Flavophospholipids was included only in the mg/PCU.

[60] National Research Council. 2012. Nutrient Requirements of Swine, Eleventh Edition. Washington, DC: National Academy Press.

Table 3. 14 Production, biomass and quantity of antimicrobials used in feed by province/region, 2012 to 2016

Province/ region	Year	Number of herds	Number of rations	Proportion of rations medicated	Average weight at exposure median (min ; max)	Average grow-finish period	Active ingredient	Grower-finisher pig weights[a]	mg/PCU		nDDDvetCA/ 1,000 GF pig-days at risk		nDDDvetCA/ PCU	
		Total	Total	%	(kg)	(Days)	(mg)	(kg)	Total	% change[b]	Total	% change[b]	Total	%change[b]
Prairies	2012	40	174	65	70 (25 ; 117)	110	662,477,198	5,006,278	132		277		30	
	2013	38	172	61	69 (23 ; 122)	109	734,172,951	5,084,913	144	9	322	16	35	15
	2014	43	205	61	68 (25 ; 118)	109	842,082,712	5,075,220	166	15	302	-6	33	-6
	2015	39	165	53	70 (25 ; 121)	111	854,877,885	5,493,810	156	-6	258	-15	29	-13
	2016	40	176	49	69 (28 ; 136)	112	548,609,650	5,438,142	101	-35	206	-20	23	-20
Ontario	2012	27	103	46	70 (27 ; 121)	110	276,336,565	2,163,265	128		192		21	
	2013	28	100	47	70 (26 ; 125)	108	232,737,107	2,205,947	106	-17	182	-5	20	-7
	2014	26	109	54	70 (27 ; 125)	110	358,536,769	2,378,448	151	43	262	44	29	47
	2015	25	96	51	70 (27 ; 125)	114	454,971,382	2,306,070	197	31	322	23	37	28
	2016	27	95	51	63 (28 ; 125)	114	298,836,760	2,422,905	123	-37	196	-39	22	-39
Québec	2012	20	62	66	69 (25 ; 120)	116	407,810,894	1,477,190	276		341		40	
	2013	23	69	65	67 (25 ; 121)	113	322,619,063	1,516,190	213	-23	266	-22	30	-24
	2014	26	79	73	63 (25 ; 118)	121	393,818,303	2,232,588	176	-17	281	6	34	12
	2015	21	67	75	58 (22 ; 119)	115	393,836,556	1,864,200	211	20	320	14	37	9
	2016	24	52	48	59 (25 ; 120)	117	262,132,293	1,744,568	150	-29	227	-29	27	-28
National[c]	2012	87	339	59	70 (25 ; 121)	111	1,346,624,657	8,646,733	156		266		30	
	2013	89	341	58	68 (23 ; 125)	110	1,289,529,122	8,807,050	146	-6	277	4	30	2
	2014	95	393	62	68 (25 ; 125)	112	1,594,437,784	9,686,255	165	12	286	3	32	6
	2015	85	328	57	67 (22 ; 125)	113	1,703,685,823	9,664,080	176	7	285	0	32	0
	2016	91	323	49	67 (25 ; 136)	114	1,109,578,703	9,605,614	116	-34	207	-28	24	-27

This analysis excludes ionophores.

mg/PCU = milligrams/population correction unit.

ESVAC = European Surveillance of Veterinary Antimicrobial Consumption.

DDDvetCA = Canadian Defined Daily Doses (average labelled dose) in milligrams per kilogram grower-finisher pig weight per day (mg_{drug}/kg_{animal}/day); please refer to Appendix: Supplemental data, Table A. 2 for the list of standards.

nDDDvetCA/1,000 GF pig-days at risk = number of DDDvetCA/1,000 grower-finisher pig-days at risk.

nDDDvet/PCU = number of DDDvetCA/population correction unit.

The Prairies is a region including the provinces of Alberta, Saskatchewan, and Manitoba.

For detailed metric description, please refer to Table 3. 1.

[a] Population correction unit (PCU) or biomass, European weight (total herd population x ESVAC standard weight of 65 kg pig).

[b] Percent change = [(current surveillance year – previous surveillance year)/previous surveillance year] x 100.

[c] Includes only the provinces/regions surveyed and includes only the quantity of antimicrobials used in feed, excluding ionophores.

Table 3. 15 Frequency and quantity of coccidiostat use in grower-finisher pigs, 2016

	Coccidiostat	Herds n (%) Total n = 91	Rations n (%) Total n = 402	Ration days exposed[a] median (min. ; max.)	Percent of herd exposed median (min. ; max.)	Weight at exposure median[b] (min. ; max.)[c]	Level of drug g/tonne[d] median (min. ; max.)
IV	Narasin	3 (3)	11 (3)	28 (14 ; 56)	100 (100 ; 100)	55 (25 ; 125)	15 (15 ; 17)
	Salinomycin	21 (23)	68 (17)	28 (7 ; 84)	100 (50 ; 100)	79 (25 ; 136)	25 (13 ; 30)
Total for medicated feed		**24 (26)**	**79 (20)**			**78 (25 ; 136)**	

Roman numeral IV indicates the ranking of antimicrobials based on importance to human medicine as outlined by the Veterinary Drugs Directorate.

[a] Ration days exposed = for rations medicated with the specific antimicrobial and do not reflect the full grow-out period.

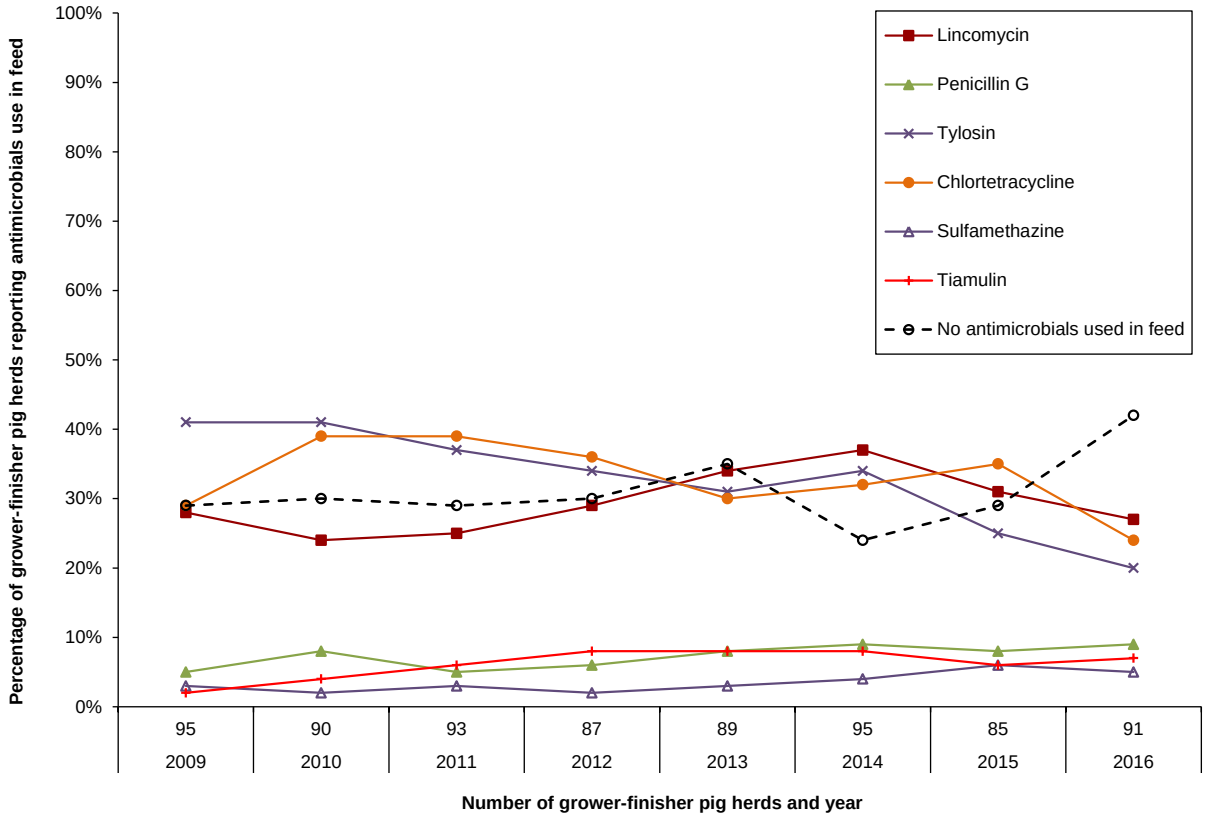
[b] Median weight at exposure = the median of all average weights of pigs exposed to a ration containing a specific antimicrobial [(Ration Start Weight + Ration End Weight)/2].

[c] Minimum (min.) and maximum (max.) pig weight at exposure = the lowest start weight and the highest end weight reported for all rations containing the specific antimicrobial, respectively.

[d] Level of drug is in grams/tonne of feed.

Antimicrobial use in feed by frequency

Figure 3. 34 Percentage of pig herds reporting antimicrobial use in feed, 2009 to 2016



Year Number of herds	2009 95	2010 90	2011 93	2012 87	2013 89	2014 95	2015 85	2016 91
Antimicrobial								
Lincomycin	**28%**	24%	25%	29%	34%	37%	**31%**	**27%**
II Penicillin G	**5%**	8%	5%	6%	8%	9%	**8%**	**9%**
Tylosin	**41%**	41%	37%	34%	31%	34%	**25%**	**20%**
Chlortetracycline	**29%**	39%	39%	36%	30%	32%	**35%**	**24%**
III Sulfamethazine	**3%**	2%	3%	2%	3%	4%	**6%**	**5%**
Tiamulin	**2%**	4%	6%	8%	8%	8%	**6%**	**7%**
No antimicrobials used in feed	**29%**	30%	29%	30%	35%	24%	**29%**	**42%**

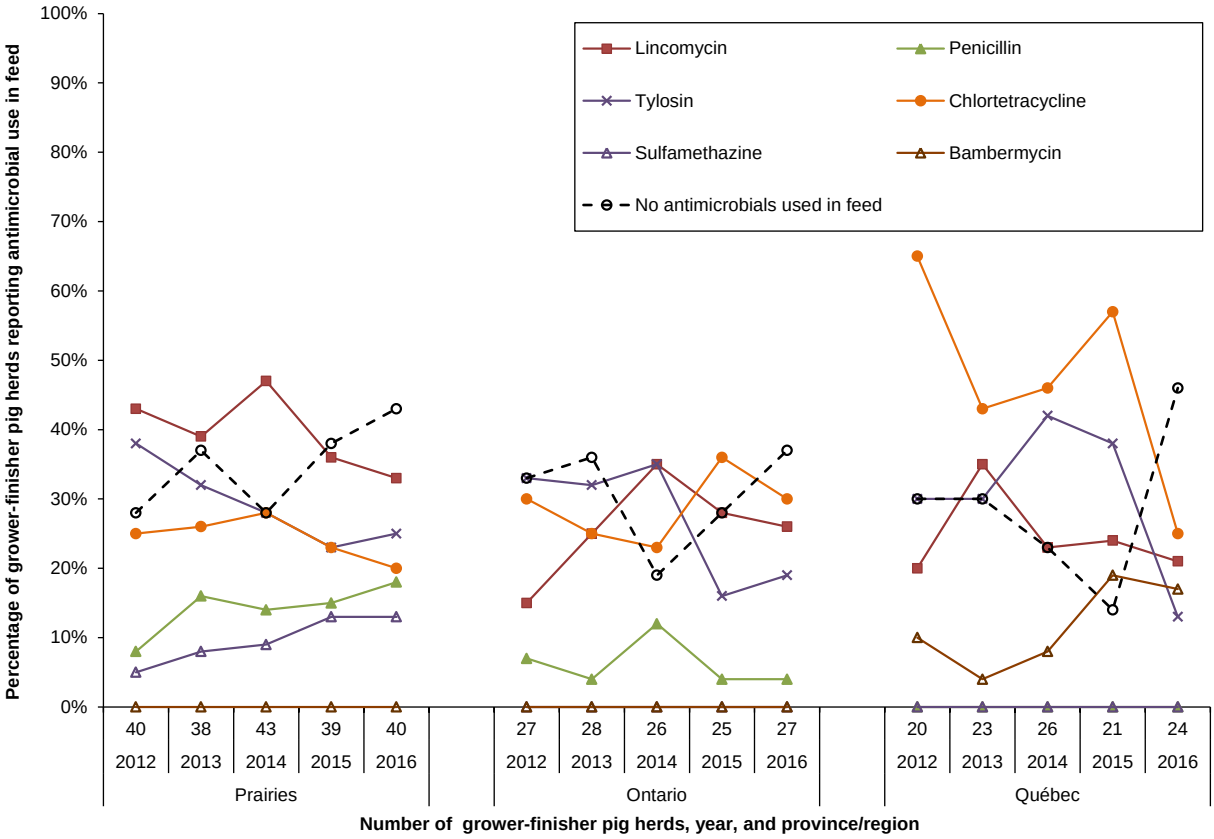
Roman numerals II to III indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

Only antimicrobials used by 5% of herds or more in a given year within any province/region are depicted in this figure. Antimicrobial use in feed reported by fewer than 5% of herds included Category II: tilmicosin, tylvalosin, virginiamycin; Category III: bacitracin, neomycin, oxytetracycline, spectinomycin; Category IV: bambermycin.

For the temporal analysis, the proportion (%) of herds using a specific antimicrobial in the current year has been compared to the proportion (%) of herds using the same antimicrobial in the first and previous surveillance year (grey areas). The presence of blue areas indicates significant temporal differences ($P \leq 0.05$) for a given antimicrobial.

The Prairies is a region including the provinces of Alberta, Saskatchewan, and Manitoba.

Figure 3. 35 Percentage of pig herds reporting antimicrobial use in feed by province / region, 2012 to 2016



Province/region		Prairies					Ontario					Québec				
Year		2012	2013	2014	2015	2016	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
Number of herds		40	38	43	39	40	27	28	26	25	27	20	23	26	21	24
Antimicrobial																
II	Lincomycin	**43%**	39%	47%	**36%**	**33%**	**15%**	25%	35%	**28%**	**26%**	**20%**	35%	23%	**24%**	**21%**
II	Penicillin	**8%**	16%	14%	**15%**	**18%**	**7%**	4%	12%	**4%**	**4%**	**0%**	0%	0%	**0%**	**0%**
II	Tylosin	**38%**	32%	28%	**23%**	**25%**	**33%**	32%	35%	**16%**	**19%**	**30%**	30%	42%	**38%**	**13%**
III	Chlortetracycline	**25%**	26%	28%	**23%**	**20%**	**30%**	25%	23%	**36%**	**30%**	**65%**	43%	46%	**57%**	**25%**
III	Sulfamethazine	**5%**	8%	9%	**13%**	**13%**	**0%**	0%	0%	**0%**	**0%**	**0%**	0%	0%	**0%**	**0%**
IV	Bambermycin	**0%**	0%	0%	**0%**	**0%**	**0%**	0%	0%	**0%**	**0%**	**10%**	4%	8%	**19%**	**17%**
	No antimicrobials used in feed	**28%**	37%	28%	**38%**	**43%**	**33%**	36%	19%	**28%**	**37%**	**30%**	30%	23%	**14%**	**46%**

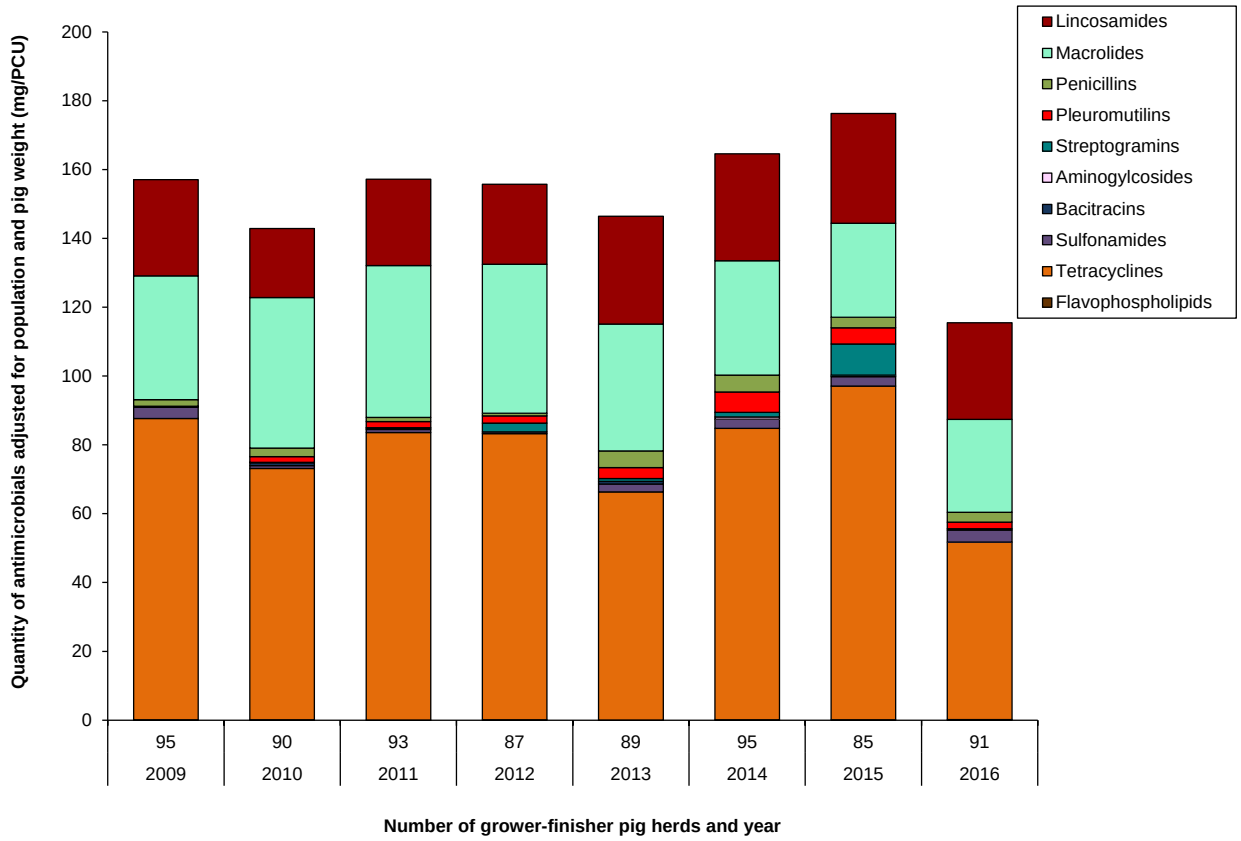
Roman numerals II to IV indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

Only antimicrobials used by 5% of herds or more in a given year within any province/region are depicted in this figure. Antimicrobial use in feed reported by fewer than 5% of herds included Category II: tilmicosin, tylvalosin and virginiamycin; Category III: bacitracin, neomycin, oxytetracycline, spectinomycin, and tiamulin.

For the temporal analyses within province/region, the proportion (%) of herds using a specific antimicrobial in the current year has been compared to the proportion (%) of herds using the same antimicrobial in the first year and the previous surveillance year (grey areas). The presence of blue areas indicates significant temporal differences within province/region ($P \leq 0.05$) for a given antimicrobial. The presence of red areas indicates significant provincial/regional differences ($P \leq 0.05$) for a given antimicrobial within the current year. The presence of purple areas (2016 surveillance year; Québec-referent province) indicates significant temporal and provincial/regional differences ($P \leq 0.05$) for a given antimicrobial.

Antimicrobial use in feed by quantitative indicators

Figure 3. 36 Quantity of antimicrobial use in feed, adjusted for population and pig weight (mg/PCU), 2009 to 2016



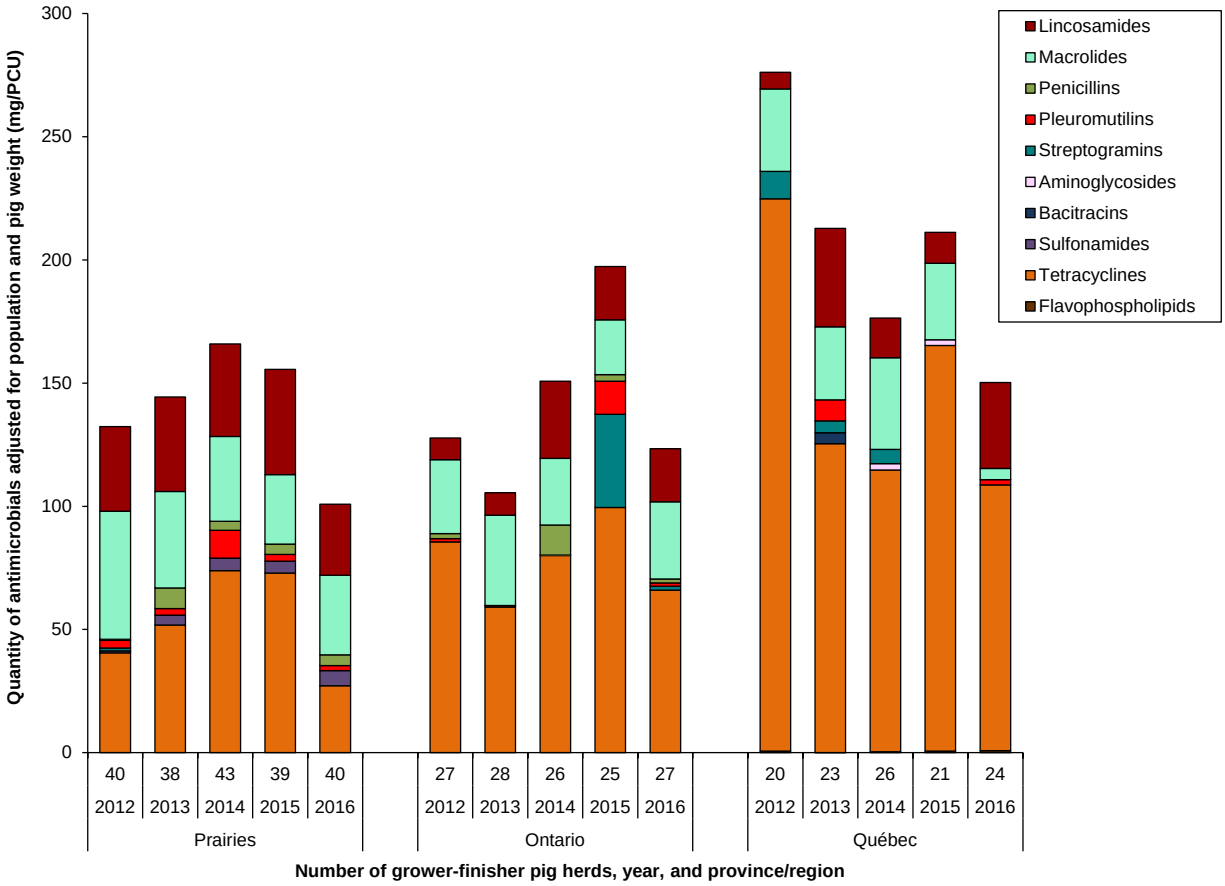
Year	2009	2010	2011	2012	2013	2014	2015	2016
Number of herds	95	90	93	87	89	95	85	91
Antimicrobial class								
II Lincosamides	28.0	20.1	25.1	23.2	31.3	31.1	31.9	28.1
II Macrolides	35.9	43.7	44.2	43.3	36.8	33.2	27.3	27.0
II Penicillins	2.0	2.5	1.2	0.8	4.9	4.9	3.0	2.9
II Pleuromutilins	< 0.1	1.7	1.8	2.1	3.2	6.0	4.7	1.9
II Streptogramins	< 0.1	< 0.1	0.1	2.6	0.8	1.3	9.0	0.4
III Aminoglycosides	0.2	0.1	0.4	0.0	0.0	0.6	0.4	0.0
III Bacitracins	0.0	0.8	0.0	0.0	0.8	0.0	0.0	0.0
III Sulfonamides	3.3	0.8	0.9	0.5	2.3	2.7	2.7	3.5
III Tetracyclines	87.5	73.0	83.6	83.1	66.3	84.7	97.0	51.6
IV Flavophospholipids	0.1	0.1	< 0.1	0.1	< 0.1	0.1	0.1	0.2
Total	**157.1**	**142.8**	**157.2**	**155.7**	**146.4**	**164.6**	**176.3**	**115.5**

Roman numerals II to IV indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

mg/PCU = milligrams/population correction unit.

For detailed indicator description, please refer to Table 3. 1.

Figure 3. 37 Quantity of antimicrobial use in feed, adjusted for population and pig weight (mg/PCU), by province/region, 2012 to 2016



Province/region		Prairies					Ontario					Québec				
Year		2012	2013	2014	2015	2016	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
Number of herds		40	38	43	39	40	27	28	26	25	27	20	23	26	21	24
Antimicrobial class																
II	Lincosamides	34	38	38	43	29	9	9	31	22	21	7	40	16	13	35
	Macrolides	52	39	34	28	32	30	37	27	22	31	33	30	37	31	5
	Penicillins	< 1	8	4	4	4	2	< 1	12	3	2	0	0	0	0	0
	Pleuromutilins	3	3	11	3	2	1	1	0	13	1	0	8	0	0	2
	Streptogramins	1	0	0	0	0	0	0	0	38	2	11	5	6	0	0
III	Aminoglycosides	0	0	0	0	0	0	0	0	0	0	0	0	3	2	0
	Bacitracins	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
	Sulfonamides	1	4	5	5	6	0	0	0	0	0	0	0	0	0	0
	Tetracyclines	41	52	74	73	27	86	59	80	100	66	224	125	114	165	108
IV	Flavophospholipids	0	0	0	0	0	0	0	0	0	0	1	< 1	< 1	1	1
Total		**132**	**144**	**166**	**156**	**101**	**128**	**106**	**151**	**197**	**123**	**276**	**213**	**176**	**211**	**150**

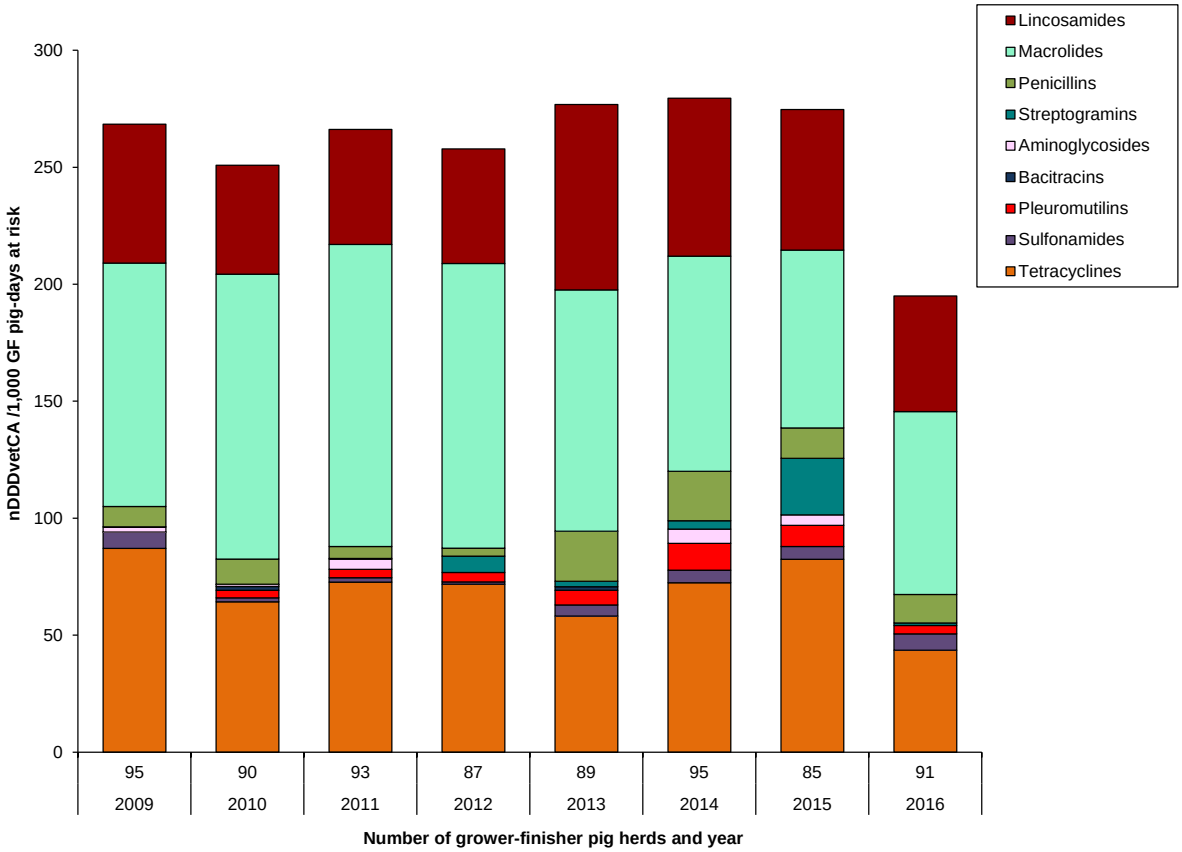
Roman numerals II to IV indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

mg/PCU = milligrams/population correction unit.

For detailed indicator description, please refer to Table 3. 1.

The Prairies is a region including the provinces of Alberta, Saskatchewan, and Manitoba.

Figure 3. 38 Number of Canadian Defined Daily Doses for animals per 1,000 grower-finisher pig-days at risk (nDDDvetCA/1,000 GF pig-days at risk) for antimicrobials administered in feed, 2009 to 2016



Year		2009	2010	2011	2012	2013	2014	2015	2016
Number of herds		95	90	93	87	89	95	85	91
Antimicrobial class									
II	Lincosamides	59	47	49	49	79	68	60	49
	Macrolides	104	122	129	122	103	92	76	78
	Penicillins	9	11	5	3	21	21	13	12
	Streptogramins	0	< 1	< 1	7	2	4	24	1
III	Aminoglycosides	2	1	4	0	0	6	4	0
	Bacitracins	0	2	0	0	2	0	0	0
	Pleuromutilins	< 1	3	4	4	6	11	9	4
	Sulfonamides	7	2	2	1	5	5	5	7
	Tetracyclines	87	64	73	72	58	72	82	44
Total		**268**	**251**	**266**	**258**	**277**	**280**	**275**	**195**

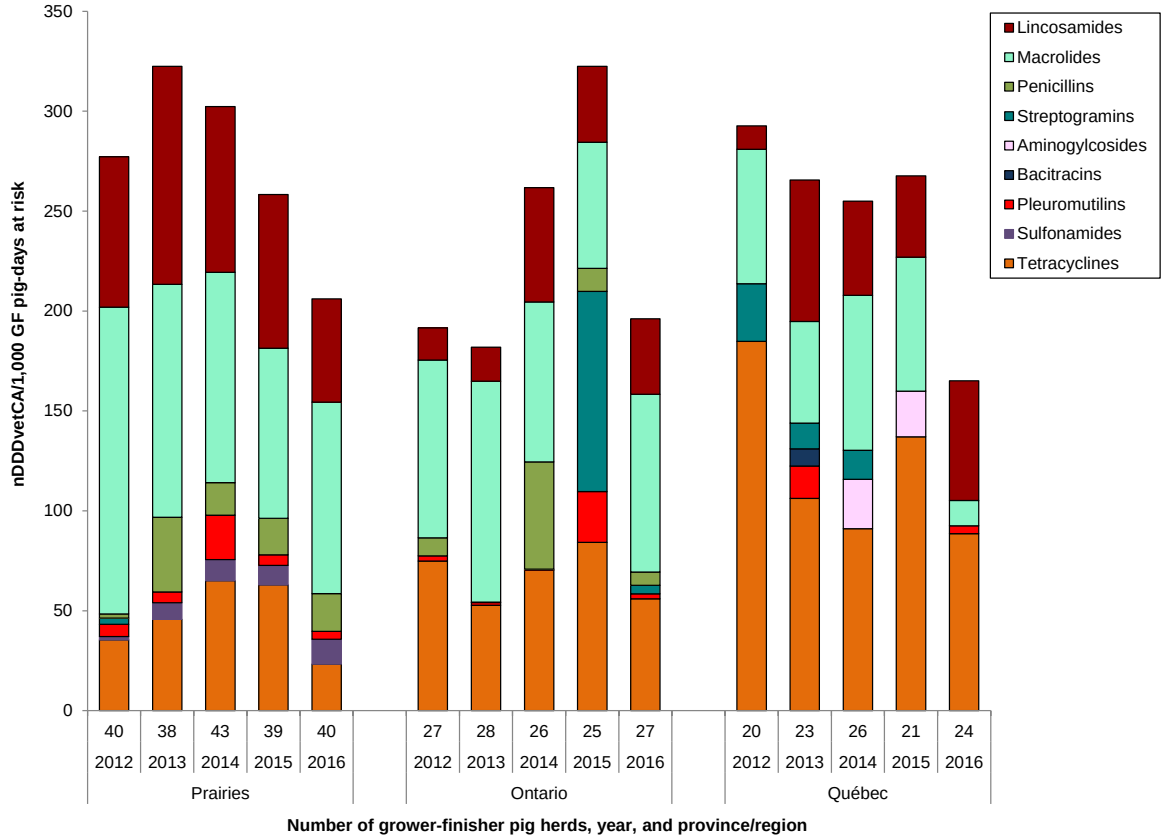
Roman numerals II to III indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

DDDvetCA = Canadian Defined Daily Doses (average labelled dose) in milligrams per kilogram grower-finisher pig weight per day (mg_{drug}/kg_{animal}/day); please refer to Appendix: Supplemental data, Table A. 2 for the list of standards.

nDDDvetCA/1,000 GF pig-days at risk = number of DDDvetCA/ 1,000 grower-finisher pig-days at risk.

For detailed indicator description, please refer to Table 3. 1.

Figure 3. 39 Number of Canadian Defined Daily Doses for animals per 1,000 grower-finisher pig-days at risk (nDDDvetCA/1,000 GF pig-days at risk) for antimicrobials administered in feed, by province/region, 2009 to 2016



Province/region		Prairies					Ontario					Québec				
Year		2012	2013	2014	2015	2016	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
Number of herds		40	38	43	39	40	27	28	26	25	27	20	23	26	21	24
Antimicrobial class																
II	Lincosamides	75	109	83	77	52	16	17	57	38	38	12	71	47	41	60
	Macrolides	154	117	105	85	96	89	111	80	63	89	67	51	78	67	13
	Penicillins	2	37	16	18	19	9	< 1	54	12	7	0	0	0	0	0
	Streptogramins	3	0	0	0	0	0	0	0	100	4	29	13	15	0	0
III	Aminogylcosides	0	0	0	0	0	0	0	0	0	0	0	0	25	23	0
	Bacitracins	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0
	Pleuromutilins	6	5	22	5	4	3	1	1	25	3	0	16	0	0	4
	Sulfonamides	2	8	11	10	12	0	0	0	0	0	0	0	0	0	0
	Tetracyclines	35	46	65	63	23	75	53	70	84	56	185	106	91	137	89
Total		**277**	**322**	**302**	**258**	**206**	**192**	**182**	**262**	**322**	**196**	**293**	**266**	**255**	**268**	**165**

Roman numerals II to III indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

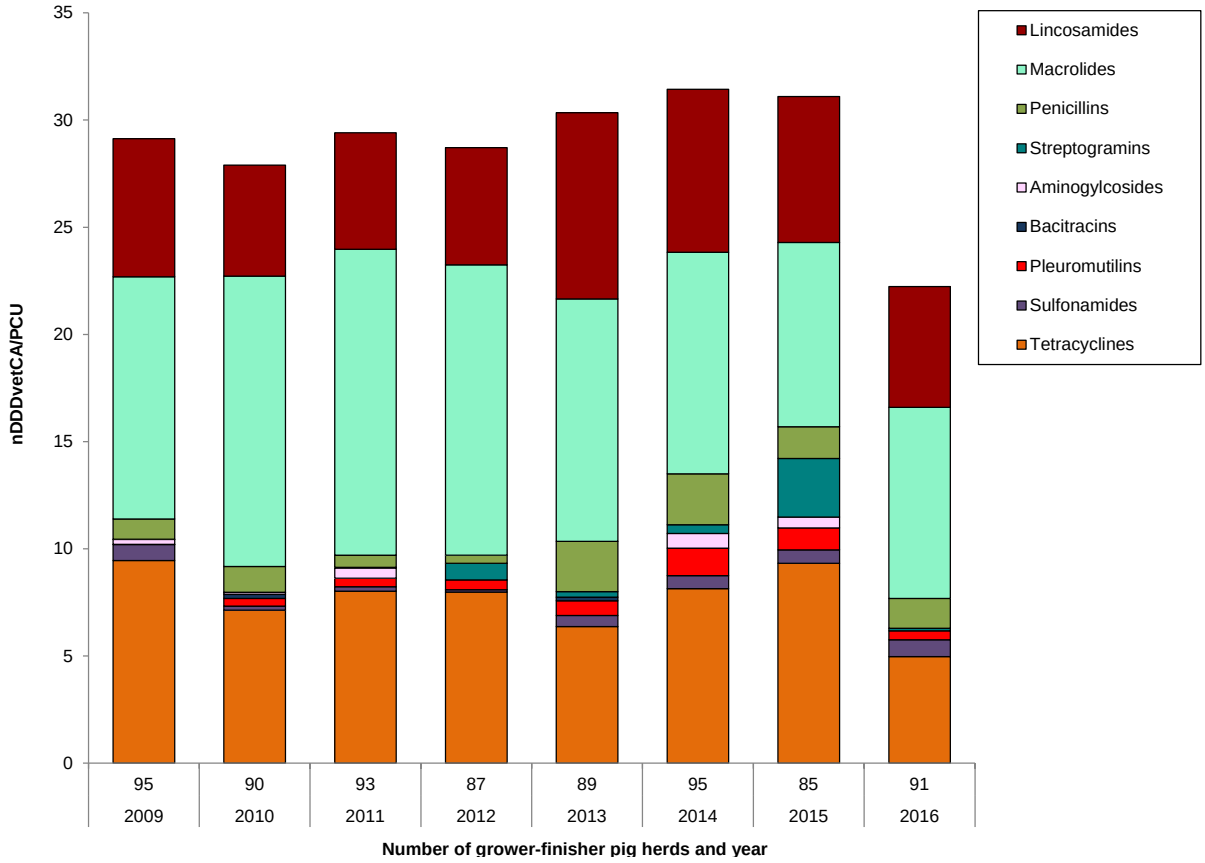
DDDvetCA = Canadian Defined Daily Doses (average labelled dose) in milligrams per kilogram grower-finisher pig weight per day (mg_{drug}/kg_{animal}/day); please refer to Appendix: Supplemental data, Table A. 2 for the list of standards.

nDDDvetCA/1,000 GF pig-days at risk = number of DDDvetCA/ 1,000 grower-finisher pig-days at risk.

For detailed indicator description, please refer to Table 3. 1.

The Prairies is a region including the provinces of Alberta, Saskatchewan and Manitoba.

Figure 3. 40 Number of Canadian Defined Daily Doses for animals per population correction unit (nDDDvetCA/PCU) for antimicrobials administered in feed, 2009 to 2016



Year		2009	2010	2011	2012	2013	2014	2015	2016
Number of herds		95	90	93	87	89	95	85	91
Antimicrobial class									
II	Lincosamides	6.4	5.2	5.4	5.5	8.7	7.6	6.8	5.6
II	Macrolides	11.3	13.5	14.3	13.5	11.3	10.3	8.6	8.9
II	Penicillins	0.9	1.2	0.6	0.4	2.4	2.4	1.5	1.4
II	Streptogramins	< 0.1	< 0.1	< 0.1	0.8	0.3	0.4	2.7	0.1
III	Aminoglycosides	0.2	0.1	0.5	0.0	0.0	0.7	0.5	0.0
III	Bacitracins	0.0	0.2	0.0	0.0	0.2	0.0	0.0	0.0
III	Pleuromutilins	< 0.1	0.4	0.4	0.5	0.7	1.3	1.0	0.4
III	Sulfonamides	0.8	0.2	0.2	0.1	0.5	0.6	0.6	0.8
III	Tetracyclines	9.5	7.1	8.0	8.0	6.4	8.1	9.3	5.0
Total		**29.1**	**27.9**	**29.4**	**28.7**	**30.3**	**31.4**	**31.1**	**22.2**

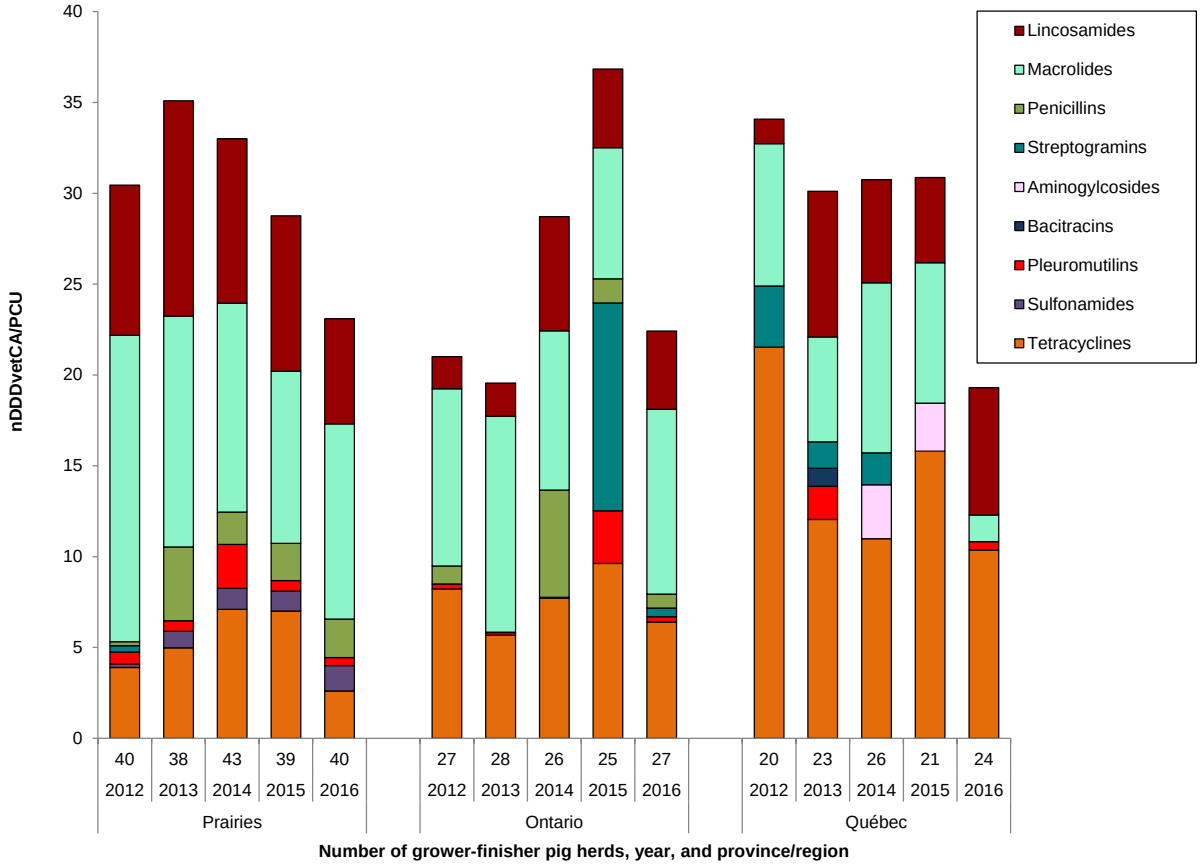
Roman numerals II to III indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

DDDvetCA = Canadian Defined Daily Doses (average labelled dose) in milligrams per kilogram grower-finisher pig weight per day (mg_{drug}/kg_{animal}/day); please refer to Appendix: Supplemental data, Table A. 2 for the list of standards.

nDDDvetCA/PCU = number of DDDvetCA/population correction unit.

For detailed indicator description, please refer to Table 3. 1.

Figure 3. 41 Number of Canadian Defined Daily Doses for animals per population correction unit (DDDvetCA/PCU) for antimicrobials administered in feed, by province/region, 2012 to 2016



Province/region		Prairies					Ontario					Québec				
Year		2012	2013	2014	2015	2016	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
Number of herds		40	38	43	39	40	27	28	26	25	27	20	23	26	21	24
Antimicrobial class																
II	Lincosamides	8.3	11.9	9.1	8.6	5.8	1.8	1.8	6.3	4.3	4.3	1.4	8.0	5.7	4.7	7.0
II	Macrolides	16.9	12.7	11.5	9.5	10.7	9.8	11.9	8.8	7.2	10.2	7.8	5.8	9.4	7.7	1.5
II	Penicillins	0.2	4.1	1.8	2.0	2.1	1.0	< 0.1	5.9	1.3	0.8	0.0	0.0	0.0	0.0	0.0
II	Streptogramins	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.4	0.5	3.4	1.5	1.8	0.0	0.0
III	Aminoglycosides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	2.6	0.0
III	Bacitracins	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
III	Pleuromutilins	0.7	0.6	2.4	0.6	0.4	0.3	0.1	0.1	2.9	0.3	0.0	1.8	0.0	0.0	0.5
III	Sulfonamides	0.2	0.9	1.2	1.1	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
III	Tetracyclines	3.9	5.0	7.1	7.0	2.6	8.2	5.7	7.7	9.6	6.4	21.5	12.0	11.0	15.8	10.4
Total		**30.5**	**35.1**	**33.0**	**28.8**	**23.1**	**21.0**	**19.5**	**28.7**	**36.8**	**22.4**	**34.1**	**30.1**	**30.8**	**30.9**	**19.3**

Roman numerals II to III indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

DDDvetCA = Canadian Defined Daily Doses (average labelled dose) in milligrams per kilogram grower-finisher pig weight per day (mg_{drug}/kg_{animal}/day); please refer to Appendix: Supplemental data, Table A. 2 for the list of standards.

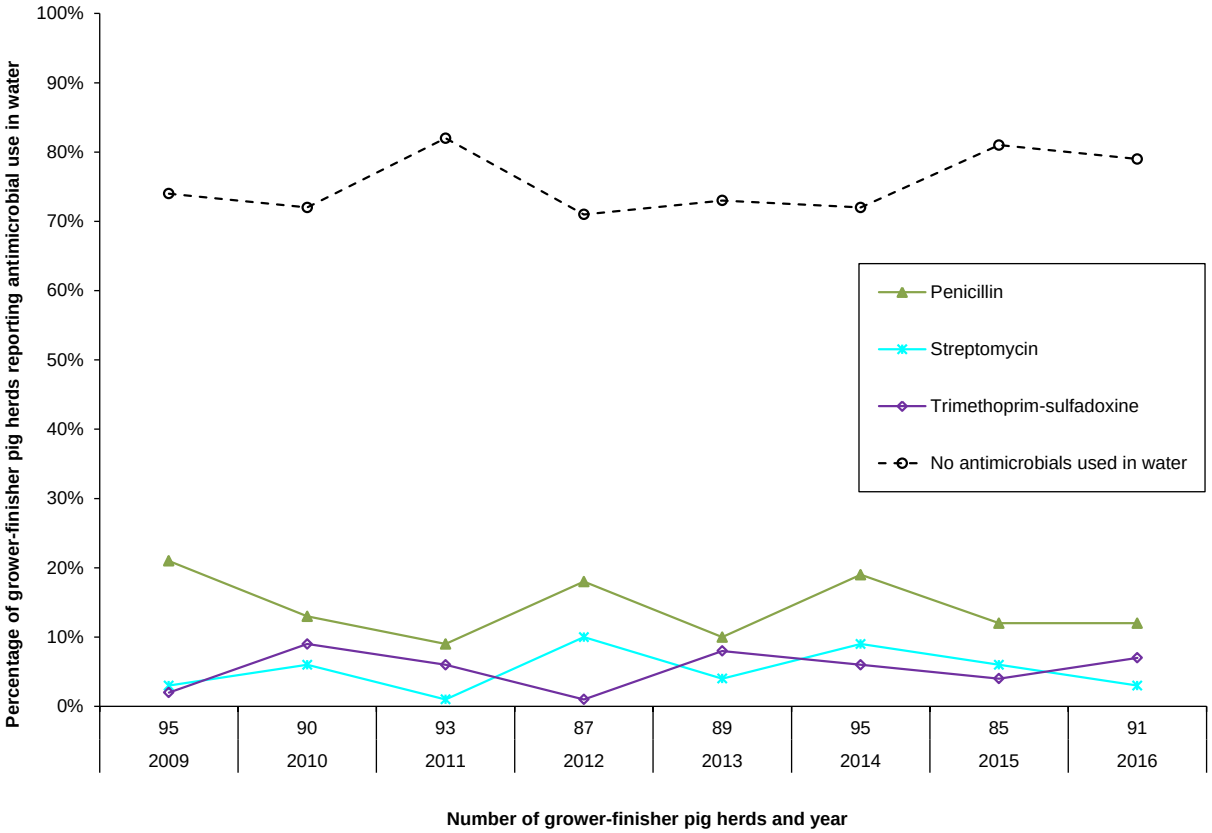
nDDDvetCA/PCU = number of DDDvetCA/population correction unit.

For detailed indicator description, please refer to Table 3. 1.

The Prairies is a region including the provinces of Alberta, Saskatchewan and Manitoba.

Antimicrobial use in water by frequency

Figure 3. 42 Percentage of pig herds reporting antimicrobial use in water, 2009 to 2016



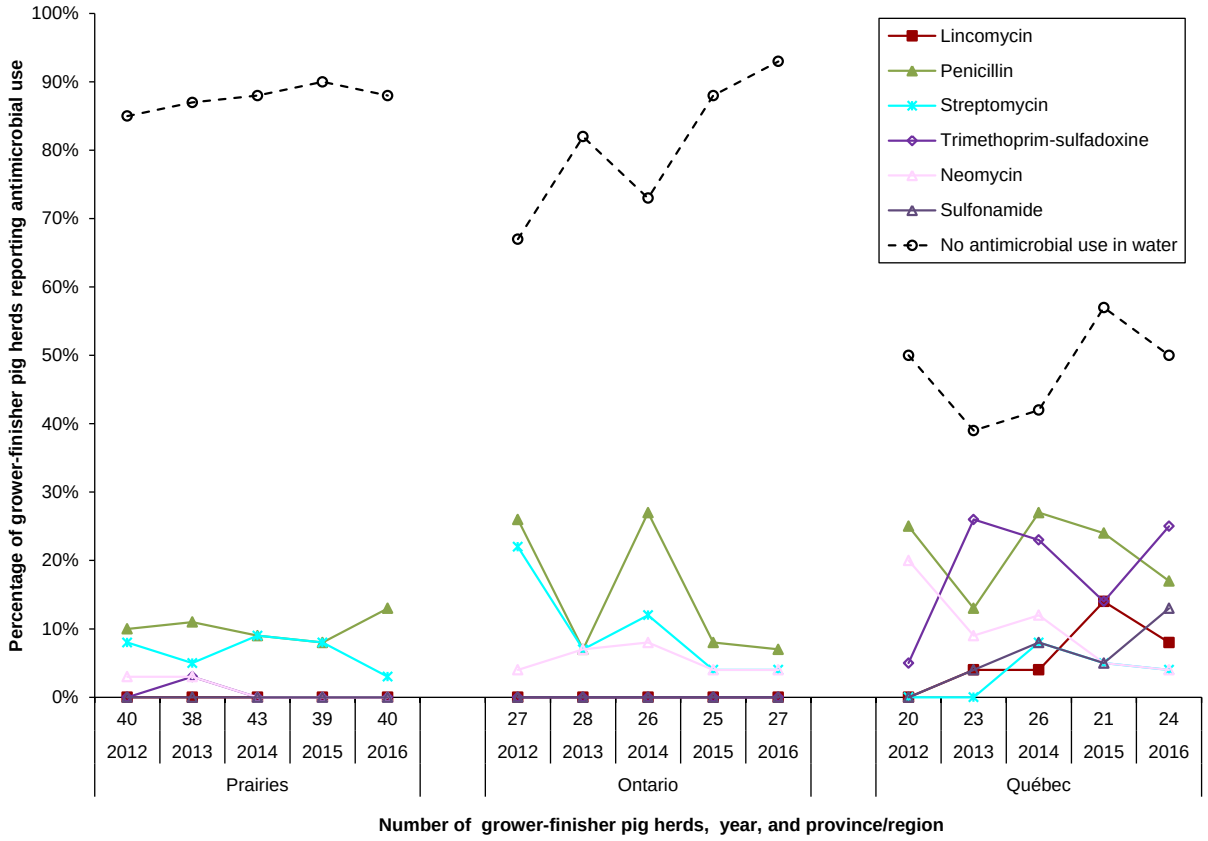
Year Number of herds	2009 95	2010 90	2011 93	2012 87	2013 89	2014 95	2015 85	2016 91
Antimicrobial								
II Penicillin	**21%**	13%	9%	18%	10%	19%	**12%**	**12%**
II Streptomycin	**3%**	6%	1%	10%	4%	9%	**6%**	**3%**
Trimethoprim-sulfadoxine	**2%**	9%	6%	1%	8%	6%	**4%**	**7%**
No antimicrobials used in water	**74%**	72%	82%	71%	73%	72%	**81%**	**79%**

Roman numerals II indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

Only antimicrobials used by 5% of herds or more in a given year are depicted in this figure. Antimicrobial use in water reported by fewer than 5% of herds included Category II: lincomycin; Category III: neomycin, spectinomycin, sulfonamides and tetracycline.

For the temporal analyses, the proportion (%) of herds using a specific antimicrobial in the current year has been compared to the proportion (%) of herds using the same antimicrobial in the first and the previous surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given antimicrobial.

Figure 3. 43 Percentage of pig herds reporting antimicrobial use in water by province / region, 2012 to 2016



Number of grower-finisher pig herds, year, and province/region

Province/region		Prairies					Ontario					Québec				
Year		2012	2013	2014	2015	2016	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
Number of herds		40	38	43	39	40	27	28	26	25	27	20	23	26	21	24
Antimicrobial																
II	Lincomycin	**0%**	0%	0%	**0%**	**0%**	**0%**	0%	0%	**0%**	**0%**	**0%**	4%	4%	**14%**	**8%**
II	Penicillin	**10%**	11%	9%	**8%**	**13%**	**26%**	7%	27%	**8%**	**7%**	**25%**	13%	27%	**24%**	**17%**
II	Streptomycin	**8%**	5%	9%	**8%**	**3%**	**22%**	7%	12%	**4%**	**4%**	**0%**	0%	8%	**5%**	**4%**
II	Trimethoprim-sulfadoxine	**0%**	3%	0%	**0%**	**0%**	**0%**	0%	0%	**0%**	**0%**	**5%**	26%	23%	**14%**	**25%**
III	Neomycin	**3%**	3%	0%	**0%**	**0%**	**4%**	7%	8%	**4%**	**4%**	**20%**	9%	12%	**5%**	**4%**
III	Sulfonamide	**0%**	0%	0%	**0%**	**0%**	**0%**	0%	0%	**0%**	**0%**	**0%**	4%	8%	**5%**	**13%**
	No antimicrobial use in water	**85%**	87%	88%	**90%**	**88%**	**67%**	82%	73%	**88%**	**93%**	**50%**	39%	42%	**57%**	**50%**

Roman numerals II to III indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

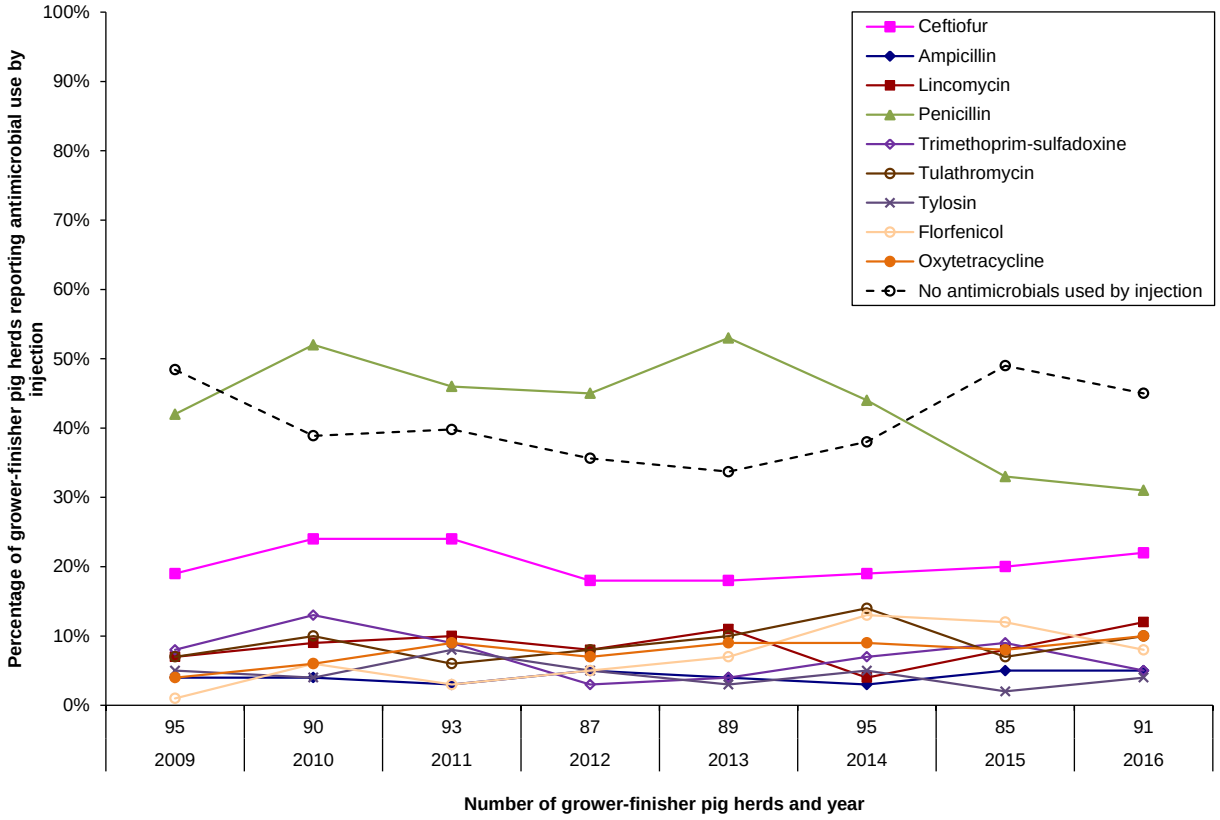
Only antimicrobials used by 5% of herds or more in a given year are depicted in this figure. Antimicrobial use in water reported by fewer than 5% of herds included Category III: spectinomycin and tetracycline.

For the temporal analyses within province/region, the proportion (%) of herds using a specific antimicrobial in the current year has been compared to the proportion (%) of herds using the same antimicrobial in the first year and the previous surveillance year (grey areas). The presence of blue areas indicates significant temporal differences within province/region ($P \leq 0.05$) for a given antimicrobial. The presence of red areas indicates significant provincial/regional differences ($P \leq 0.05$) for a given antimicrobial within the current year. The presence of purple areas (2016 surveillance year; Québec-referent province) indicates significant temporal and provincial/regional differences ($P \leq 0.05$) for a given antimicrobial.

The Prairies is a region including the provinces of Alberta, Saskatchewan and Manitoba.

Antimicrobial use by injection by frequency

Figure 3. 44 Percentage of pig herds reporting antimicrobial use by injection, 2009 to 2016



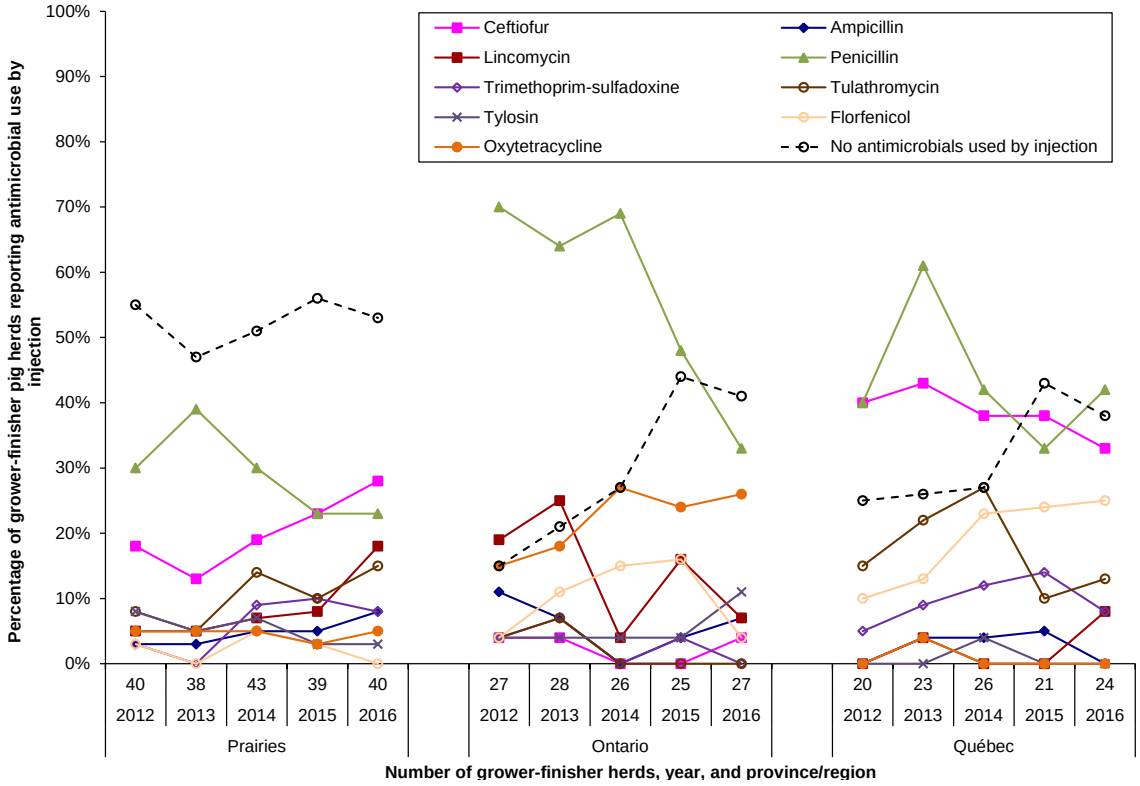
Year Number of herds		2009 95	2010 90	2011 93	2012 87	2013 89	2014 95	2015 85	2016 91
Antimicrobial									
I	Ceftiofur	**20%**	24%	24%	18%	18%	19%	**20%**	**22%**
II	Ampicillin	**4%**	4%	3%	5%	4%	3%	**5%**	**5%**
	Lincomycin	**8%**	9%	10%	8%	11%	4%	**8%**	**12%**
	Penicillin	**41%**	51%	46%	45%	53%	44%	**33%**	**31%**
	Trimethoprim-sulfadoxine	**9%**	13%	9%	3%	4%	7%	**9%**	**5%**
	Tulathromycin	**8%**	10%	6%	8%	10%	14%	**7%**	**10%**
	Tylosin	**5%**	4%	8%	5%	3%	5%	**2%**	**4%**
III	Florfenicol	**1%**	6%	3%	5%	7%	13%	**12%**	**8%**
	Oxytetracycline	**4%**	6%	9%	7%	9%	9%	**8%**	**10%**
	No antimicrobials used by injection	**47%**	40%	40%	36%	34%	38%	**49%**	**45%**

Roman numerals I to III indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

Only antimicrobials used by 5% of herds or more in a given year are depicted in this figure. Antimicrobial use by injection reported by fewer than 5% of herds included Category II: erythromycin; Category III: spectinomycin and tiamulin.

For the temporal analyses, the proportion (%) of herds using a specific antimicrobial in the current year has been compared to the proportion (%) of herds using the same antimicrobial in the first and the previous surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given antimicrobial.

Figure 3. 45 Percentage of pig herds reporting antimicrobial use by injection, by province / region, 2012 to 2016



Province/region		Prairies					Ontario					Québec				
Year		2012	2013	2014	2015	2016	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
Number of herds		40	38	43	39	40	27	28	26	25	27	20	23	26	21	24
Antimicrobial																
I	Ceftiofur	**18%**	13%	19%	**23%**	**28%**	**4%**	4%	0%	**0%**	**4%**	**40%**	43%	38%	**38%**	**33%**
II	Ampicillin	**3%**	3%	5%	**5%**	**8%**	**11%**	7%	0%	**4%**	**7%**	**0%**	4%	4%	**5%**	**0%**
II	Lincomycin	**5%**	5%	7%	**8%**	**18%**	**19%**	25%	4%	**16%**	**7%**	**0%**	4%	0%	**0%**	**8%**
II	Penicillin	**30%**	39%	30%	**23%**	**23%**	**70%**	64%	69%	**48%**	**33%**	**40%**	61%	42%	**33%**	**42%**
II	Trimethoprim-sulfadoxine	**3%**	0%	9%	**10%**	**8%**	**4%**	7%	0%	**4%**	**0%**	**5%**	9%	12%	**14%**	**8%**
II	Tulathromycin	**8%**	5%	14%	**10%**	**15%**	**4%**	7%	0%	**0%**	**0%**	**15%**	22%	27%	**10%**	**13%**
II	Tylosin	**8%**	5%	7%	**3%**	**3%**	**4%**	4%	4%	**4%**	**11%**	**0%**	0%	4%	**0%**	**0%**
III	Florfenicol	**3%**	0%	5%	**3%**	**0%**	**4%**	11%	15%	**16%**	**4%**	**10%**	13%	23%	**24%**	**25%**
III	Oxytetracycline	**5%**	5%	5%	**3%**	**5%**	**15%**	18%	27%	**24%**	**26%**	**0%**	4%	0%	**0%**	**0%**
	No antimicrobials used by injection	**55%**	47%	51%	**56%**	**53%**	**15%**	21%	27%	**44%**	**41%**	**25%**	26%	27%	**43%**	**38%**

Roman numerals I to III indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

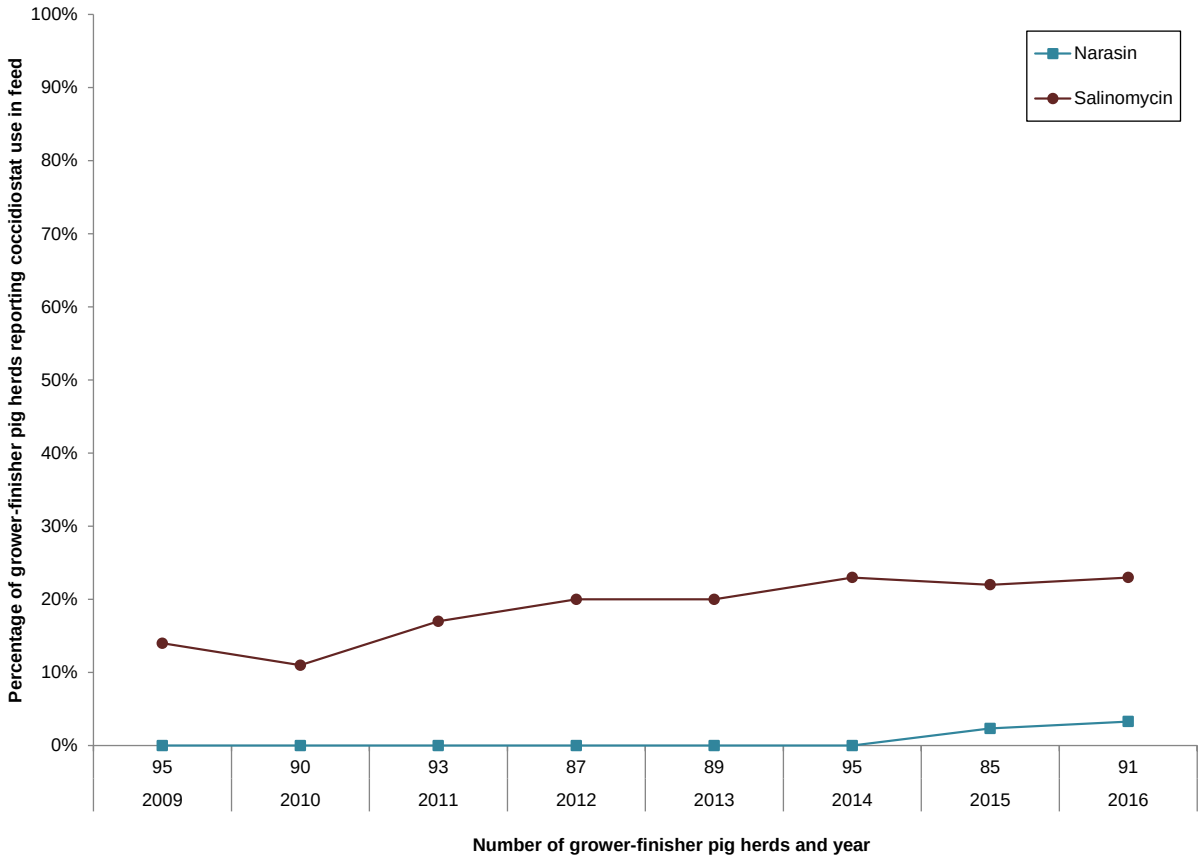
Only antimicrobials used by 5% of herds or more in a given year within any province/region are depicted in this figure. Antimicrobial use by injection reported by fewer than 5% of herds included Category II: erythromycin; Category III: spectinomycin and tiamulin.

For the temporal analyses, the proportion (%) of herds using a specific antimicrobial in the current year has been compared to the proportion (%) of herds using the same antimicrobial in the first year and the previous surveillance year (grey areas). The presence of blue areas indicates significant temporal differences within province/region ($P \leq 0.05$) for a given antimicrobial. The presence of red areas indicates significant provincial/regional differences ($P \leq 0.05$) for a given antimicrobial within the current year. The presence of purple areas (2016 surveillance year; Québec-referent province) indicates significant temporal and provincial/regional differences ($P \leq 0.05$) for a given antimicrobial.

The Prairies is a region including the provinces of Alberta, Saskatchewan, and Manitoba.

Coccidiostat use in feed by frequency

Figure 3. 46 Percentage of pig herds reporting coccidiostat use in feed, 2009 to 2016

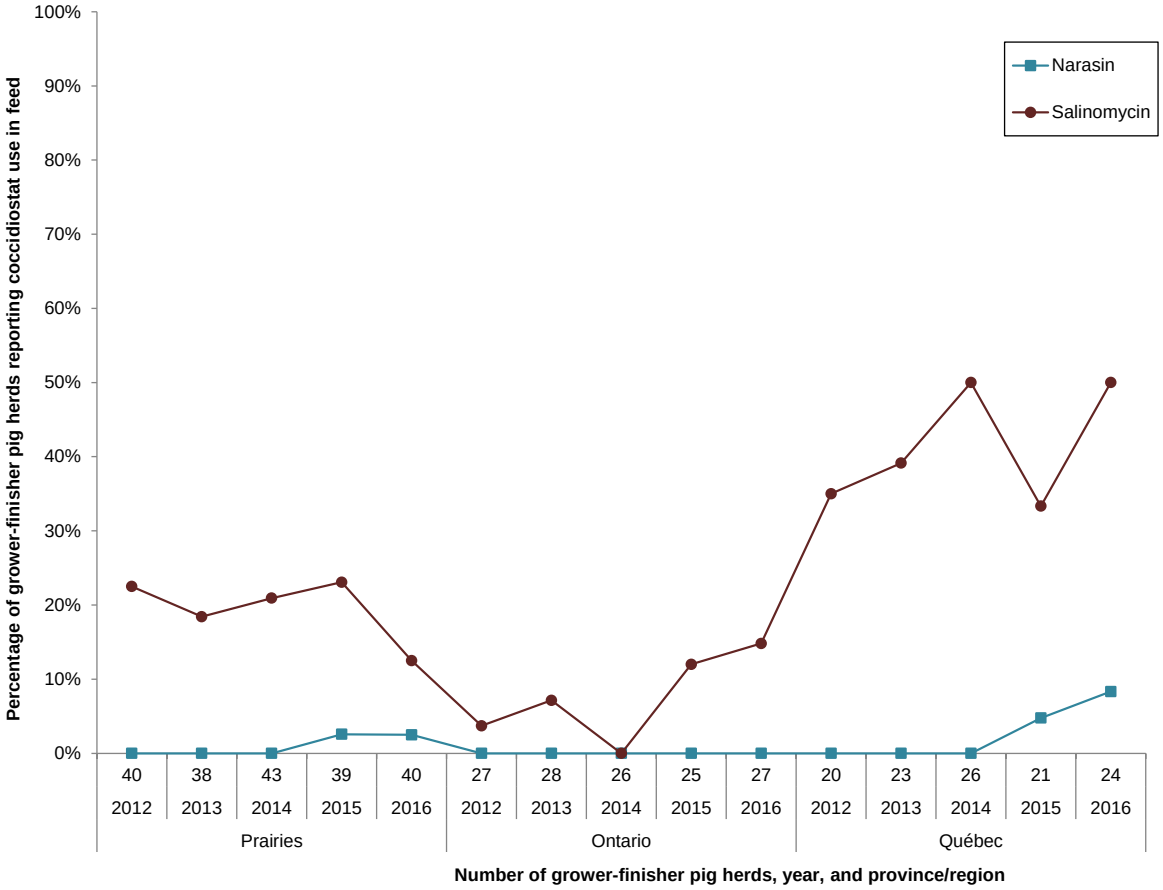


Year	2009	2010	2011	2012	2013	2014	2015	2016
Number of herds	95	90	93	87	89	95	85	91
Coccidiostat								
IV Narasin	**0%**	0%	0%	0%	0%	0%	**2%**	**3%**
IV Salinomycin	**14%**	11%	17%	20%	20%	23%	**22%**	**23%**

Roman numeral IV indicates the ranking of antimicrobials based on importance to human medicine as outlined by the Veterinary Drugs Directorate.

For the temporal analyses, the proportion (%) of herds using a specific coccidiostat in the current year has been compared to the proportion (%) of herds using the same coccidiostat in the first and the previous surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given coccidiostat.

Figure 3. 47 Percentage of pig herds reporting coccidiostat use in feed, by province / region, 2012 to 2016



Province/region	Prairies					Ontario					Québec				
Year	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
Number of herds	40	38	43	39	40	27	28	26	25	27	20	23	26	21	24
Coccidiostat															
IV Narasin	**0%**	0%	0%	**3%**	**3%**	**0%**	0%	0%	**0%**	**0%**	**0%**	0%	0%	**5%**	**8%**
IV Salinomycin	**23%**	18%	21%	**23%**	**13%**	**4%**	7%	0%	**12%**	**15%**	**35%**	39%	50%	**33%**	**50%**

Roman numeral IV indicates the ranking of antimicrobials based on importance to human medicine as outlined by the Veterinary Drugs Directorate.

For the temporal analyses, the proportion (%) of herds using a specific ionophore in the current year has been compared to the proportion (%) of herds using the same antimicrobial in the first year and the previous surveillance year (grey areas). The presence of blue areas indicates significant temporal differences within province/region ($P \leq 0.05$) for a given ionophore. The presence of red areas indicates significant provincial/regional differences ($P \leq 0.05$) for a given ionophore within the current year. The presence of purple areas (2016 surveillance year; Québec-referent province) indicates significant temporal and provincial/regional differences ($P \leq 0.05$) for a given ionophore.

Farm Surveillance in turkeys

Key findings

Seventy-two sentinel turkey farms were surveyed in 2016. For the program the flock is the unit of interest and is defined as a group of birds hatched and delivered/placed in a single production unit (barn, floor or pen) on approximately the same day. One unique flock per farm was sampled. Data presented in this section represent 1 turkey grow-out cycle/farm only. The flocks represent all the marketing/weight categories: broilers at 5.5 kg average (17 flocks); light hens at 7.2 kg average (16 flocks); heavy hens at 9.4 kg average (8 flocks); light toms at 12.2 kg average (3 flocks), and heavy toms at 15.1 kg average(28 flocks). Poults (newly hatched turkeys) placed in 53 barns were sourced from 8 Canadian Hatcheries Federation (CHF) members and the poults placed in 19 flocks were from other hatcheries (non-CHF member) including the United States. Nine flocks (13%, 9/72) (Table 3. 16) or 9% of the total turkey population sampled (52,293/558,396)[61] reported not using antimicrobials during the grow-out period. These were flocks raised without antibiotics (RWA) and organic (no use of any antibiotics, ionophores, and chemical coccidiostats). Antimicrobials administered via feed represented the greatest route of administration/exposure in terms of frequency (87%, 63/72 flocks), mg/PCU (99%, 60/60.5 mg/PCU) (Figure 3. 48), nDDDvetCA/1,000 turkey-days at risk (98%, 102/104 nDDDvetCA/1,000 1,000 turkey-days at risk) and nDDDvetCA/PCU (98%, 8.8/9 nDDDvet/PCU) (Table 3. 16).

There were provincial/regional variations in mg/PCU, nDDDvetCA/1,000 turkey-days at risk and nDDDvetCA/PCU noted and were relatively higher in Ontario compared to the national estimate and the 2 other provinces included in the surveillance program (British Columbia and Québec).

Eighty-one percent (58/72) of turkey producers reported that the poults delivered to their barn were medicated at the hatchery. Gentamicin, administered by injection, was the drug of choice for the prevention of neonatal diseases such as avian pathogenic *E. coli* (APEC) at the hatchery level.

When data from all routes of administration were combined, vast majority of the quantity of antimicrobials were used for disease prevention (95%, 57/61 mg/PCU); the contribution of antimicrobials used for disease treatment (3 mg/PCU) and growth promotion (less than 1 mg/PCU) were relatively small[62].

No turkey producers reported the use of Veterinary Drugs Directorate Category I antimicrobial in any route of administration.

[61] Biomass for 2016 surveillance year (558,396 x 6.5 kg = 3,629,571). The standard turkey weight of 6.5 kg is based on the European Surveillance for Veterinary Antimicrobial Consumption.

[62] A small amount of flavophospholipids (bambermycin), used in 3 flocks in Ontario was included in this estimate to determine overall growth promotion use; this estimate slightly differed to the data presented in Table 3. 17 and Figure 3. 49 (60 mg/PCU).

Administration in feed

Overall, 87% (63/72) of turkey producers reported AMU in feed (Figure 3. 49); the antimicrobials used belonged to Categories II and IV.

There were 402 feed rations reported in the 2016 questionnaires and of these, 127 rations (32%) were unmedicated (Table 3. 17) and these were the finisher or withdrawal rations used in conventional flocks and all the rations fed throughout the grow-out period to RWA and organic flocks. Provincial variations in the frequency of AMU were observed in 2017; the number of Ontario producers that reported no use of any antimicrobial via feed was relatively higher in Ontario (7 flocks) compared to British Columbia (1 flock) and Québec (1 flock).

Virginiamycin and bacitracin were reported used in all provinces sampled. Virginiamycin was the most frequently used antimicrobial (38%, 27/72), followed by bacitracin (36%, 26/72) (Figure 3. 49). These antimicrobials were used for the prevention of enteric diseases such as necrotic enteritis (caused by *Clostridium perfringens*). Trimethoprim-sulfadiazine was used for the treatment of APEC in 4 flocks (6%, 4/72 [Figure 3. 49]: 3 Ontario flocks and 1 Québec flock).

In terms of antimicrobial quantity, Ontario had the highest mg/PCU (86 mg/PCU) and was relatively higher compared to the national estimate (60 mg/PCU) (Figure 3. 50). Similar results were observed using nDDDvetCA/1,000 turkey-days at risk (139 nDDDvetCA/1,000 turkey-days at risk in Ontario compared to national at 102 nDDDvetCA/1,000 turkey-days at risk) (Figure 3. 51) and nDDDvetCA/PCU (12 nDDDvetCA/PCU in Ontario compared to 9 nDDDvetCA/PCU national) (Figure 3. 52).

Overall, the number of turkey producers reporting AMU for growth promotion was relatively low in 2016 (4%, 3/72 flocks) and contributed to only less than 1% of the overall quantity of antimicrobials used in 2016 (Table 3. 16).

Administration in water

Eleven percent (8/72) of turkey producers reported AMU in water (Table 3. 16). Only 1 turkey producer consulted a veterinarian or had a veterinary prescription available (i.e., for amoxicillin). There were 6 different antimicrobials used, including penicillins and tetracyclines and their combinations (i.e., with aminoglycosides such as streptomycin and neomycin) (Figure 3. 53).

The antimicrobials used via water were largely for disease treatment. Depending on the metric utilized, antimicrobials administered via water contributed to only 1% (less than 1 mg/PCU, [Figure 3. 48 and Figure 3. 54]) to 2% (2 nDDDvetCA/1,000 turkey-days at risk [Figure 3. 55] and 0.15 nDDDvetCA/PCU [Figure 3. 56]) of the total quantity of antimicrobials used in turkeys.

Administration *in ovo* or subcutaneous injection

Gentamicin (dose: 1 mg/poult) was used in 81% (58/72) of the flocks surveyed (Figure 3. 57).

The reported reason for any hatchery-level antimicrobial use was for disease prevention.

The overall contribution of hatchery-level administration was less than 1% of the total quantity of antimicrobials used in turkeys (0.13 mg/PCU [Figure 3. 58]; 0.14 nDDDvetCA/1,000 turkey-days at risk [Figure 3. 59], and; 0.1 nDDDvetCA/PCU [Figure 3. 60]).

Ionophores, chemical coccidiostats and other antiprotozoal agents

Ionophores, belonging to VDD Category IV, and other drugs that have no current VDD Category at the time of writing of this report (e.g., arsenicals and chemical coccidiostats) are presented in Figure 3. 61.

The ionophores were used in 83% (60/72) of flocks. Among the coccidiostats the most frequently used was lasalocid (47%, 34/72 flocks or 19%, 129/685 total feed rations). Overall reported chemical coccidiostat use was relatively low (6%, 4/72 flocks). Nitarsone, an arsenical used for the prevention of histomoniasis (blackhead) was reported used in 3 flocks.

Summary of antimicrobials use by all routes of administration

Table 3. 16. Number of turkey flocks with reported antimicrobial use by route of administration, 2016

Antimicrobial use	Route of administration			
	Any route[a] n (%)	*In ovo*/subcutaneous n (%)	Feed n (%)	Water n (%)
Any antimicrobial use	63 (87)	58 (81)	63 (87)	8 (11)
No antimicrobial use[b]	9 (13)	14 (19)	9 (13)	64 (89)
Total flocks	**72 (100)**	**72 (100)**	**72 (100)**	**72 (100)**

[a] Flocks with reported use of an antimicrobial class by feed, water, *in ovo*/subcutaneous, or any combination of these routes are included in each count.

[b] These were flocks raised without antibiotics including coccidiostats and organic.

Table 3. 17 Frequency and quantity of antimicrobial use in turkeys, 2016

Route of administration	Antimicrobial	Flocks n (%)	Ration n (%)	Days exposed median (min. ; max.)[a]	Level of drug median (min. ; max.)[b]	Quantity of antimicrobial active ingredient[c]		
						mg/PCU	nDDDvetCA/ 1,000 turkey-days at risk	nDDDvetCA/ PCU
Feed					g/tonne			
II	Tylosin	5 (7)	23 (6)	14 (8 ; 21)	22 (22 ; 22)	3	1	0.10
	Penicillin G procaine	5 (7)	7 (2)	14 (14 ; 14)	33 (33 ; 110)	1	1	0.10
	Virginiamycin	27 (38)	113 (29)	14 (4 ; 40)	22 (22 ; 22)	12	48	4.15
	Trimethoprim-sulfadiazin	4 (6)	4 (1)	8 (6 ; 27)	300 (200 ; 400)	2	5	0.47
III	Bacitracin	26 (36)	112 (28)	14 (1 ; 28)	55 (55 ; 110)	37	43	3.70
	Chlortetracycline	2 (3)	2 (1)	21 (21 ; 21)	440 (440 ; 440)	4	3	0.22
	Oxytetracycline	2 (3)	4 (1)	25 (18 ; 31)	440 (220 ; 660)	1	1	0.08
IV	Bambermycin	3 (4)	6 (2)	14 (10 ; 21)	2 (2 ; 2)	0	5	0.44
No AMU in feed		9 (13)	127 (32)					
Total feed, medicated		**63 (87)**	**402 (68)**			**60**	**102**	**8.81**
Water					g/Liter			
II	Amoxicillin	2 (3)	1	5 (5 ; 5)	0.2 (0.2 ; 0.2)	0.1	0.6	0.05
	Penicilline G potassium	3 (4)	2	6 (5 ; 6)	0.2 (0.2 ; 0.2)	0.1	0.2	0.02
	Penicillin-streptomycin	1 (1)	6	6 (3 ; 8)	0.1 (0.02 ; 0.1)	0.1	0.3	0.03
III	Neomycin	1 (1)	1	5 (5 ; 5)	0.1 (0.1 ; 0.1)	0.1	0.3	0.02
	Oxytetracycline-neomycin	1 (1)	2	3 (3 ; 3)	0.2 (0.1 ; 0.2	0.1	0.2	0.02
	Tetracyclin-neomycin	1 (1)	2	5 (5 ; 5)	0.2 (0.2 ; 0.2)	< 0.1	0.1	0.01
No AMU in water		64 (89)						
Total water, medicated		**8 (11)**	**14**			**0.6**	**1.8**	**0.15**
Injection					mg/egg or poult			
II	Gentamicin	58 (81)			1	0.1	0.1	0.01
No AMU via injection		14 (19)						
Total injection		**58 (81)**				**0.1**	**0.1**	**0.01**
All routes[c]						**60**	**104**	**8.97**

See corresponding footnotes on next page.

Table 3. 17 Frequency and quantity of antimicrobial use in turkeys, 2016 (continued)

Roman numerals II to IV indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

ESVAC = European Surveillance of Veterinary Antimicrobial Consumption. AMU = antimicrobial use.

Combination antimicrobials include the values for both antimicrobial components. Grey shaded cells = no data or calculations/values are not applicable for turkeys.

mg/PCU = milligrams/population correction unit.

DDDvetCA = Canadian Defined Daily Doses for animals (average labelled dose) in milligrams per kilogram turkey per day (mg_{drug}/kg_{animal}/day); please refer to Appendix: Supplemental data, Table A. 1 for the list of standards.

nDDDvetCA/1,000 turkey-days at risk = number of DDDvetCA/1,000 turkey-days at risk.

nDDDvetCA/PCU = number of DDDvetCA/population correction unit.

For detailed indicator description, please refer to Table 3. 1.

[a] Days exposed are by ration (not full grow-out) or 1 course of water treatment.

[b] Level of drug is in grams/tonne of feed or grams/liter drinking water. In water, “grams” is the inclusion rate multiplied by the concentration of the drug in that product. In poults or hatching eggs, level of drug is in milligrams per poult or hatching egg, as reported by the veterinarian/producer.

[c] Total quantity of antimicrobials were calculated based on feed or water consumed (feed and water were estimated based on breed standards). The final mg/PCU, nDDDvetCA/1,000 turkey-days at risk and nDDDvetCA/PCU exclude coccidiostats, pyrimethamine, and arsenicals. Flavophospholipids was included only in the total mg/PCU.

Table 3. 18 Production, biomass and quantity of antimicrobials used, by province / region, 2016

Province/ region	Year	Number of flocks	Preharvest weight Mean (kg)	Age sampled Mean (days)	Active ingredient (mg)	Turkey weights[a] (kg)	mg/PCU	nDDDvetCA/1,000 turkey-days at risk	nDDDvetCA/PCU
British Columbia	2016	30	9	88	96,093,296	1,973,663	49	88	8
Ontario	2016	30	10	91	102,433,244	1,170,514	88	143	12
Québec	2016	12	12	96	20,915,816	485,394	43	73	6
National[b]	2016	72	10	90	219,442,355	3,629,571	60	104	9

mg/PCU = milligrams/population correction unit.

ESVAC = European Surveillance of Veterinary Antimicrobial Consumption.

DDDvetCA = Canadian Defined Daily Doses for animals (average labelled dose) in milligrams per kilogram turkey per day (mg_{drug}/kg_{animal}/day); please refer to Appendix: Supplemental data, Table A. 1 for the list of standards.

nDDDvetCA/1,000 turkey-days at risk = number of DDDvetCA/1,000 turkey-days at risk.

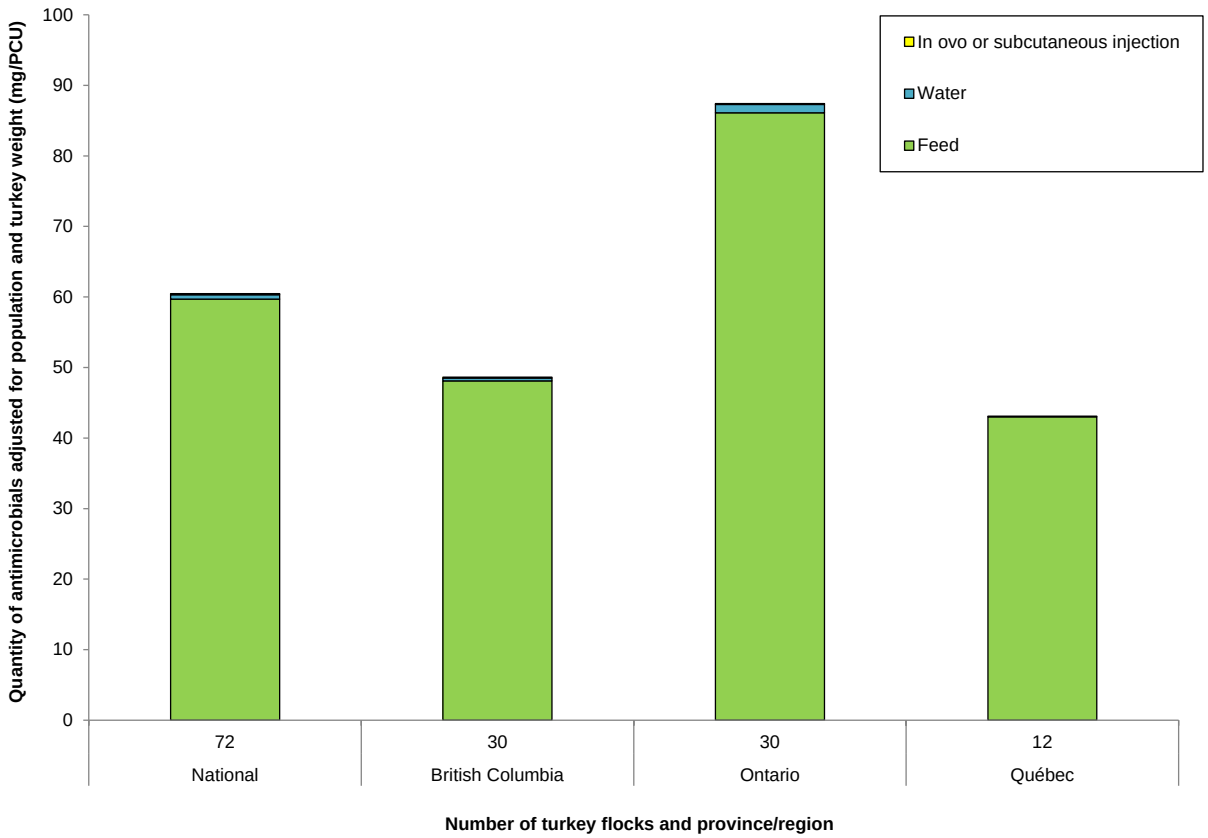
nDDDvetCA/PCU = number of DDDvetCA/population correction unit.

For detailed indicator description, please refer to Table 3. 1.

[a] Population correction unit (PCU) or biomass, European weight (total flock population x ESVAC standard weight of 6.5 kg bird).

[b] Includes only the provinces/regions surveyed and combines the quantity of antimicrobials used in feed, water and injection excluding coccidiostats, antiprotozoals, arsenicals and flavophospholipids.

Figure 3. 48 Overall quantity of antimicrobial use in all routes of administration, adjusted for population and turkey weight (mg/PCU), 2016



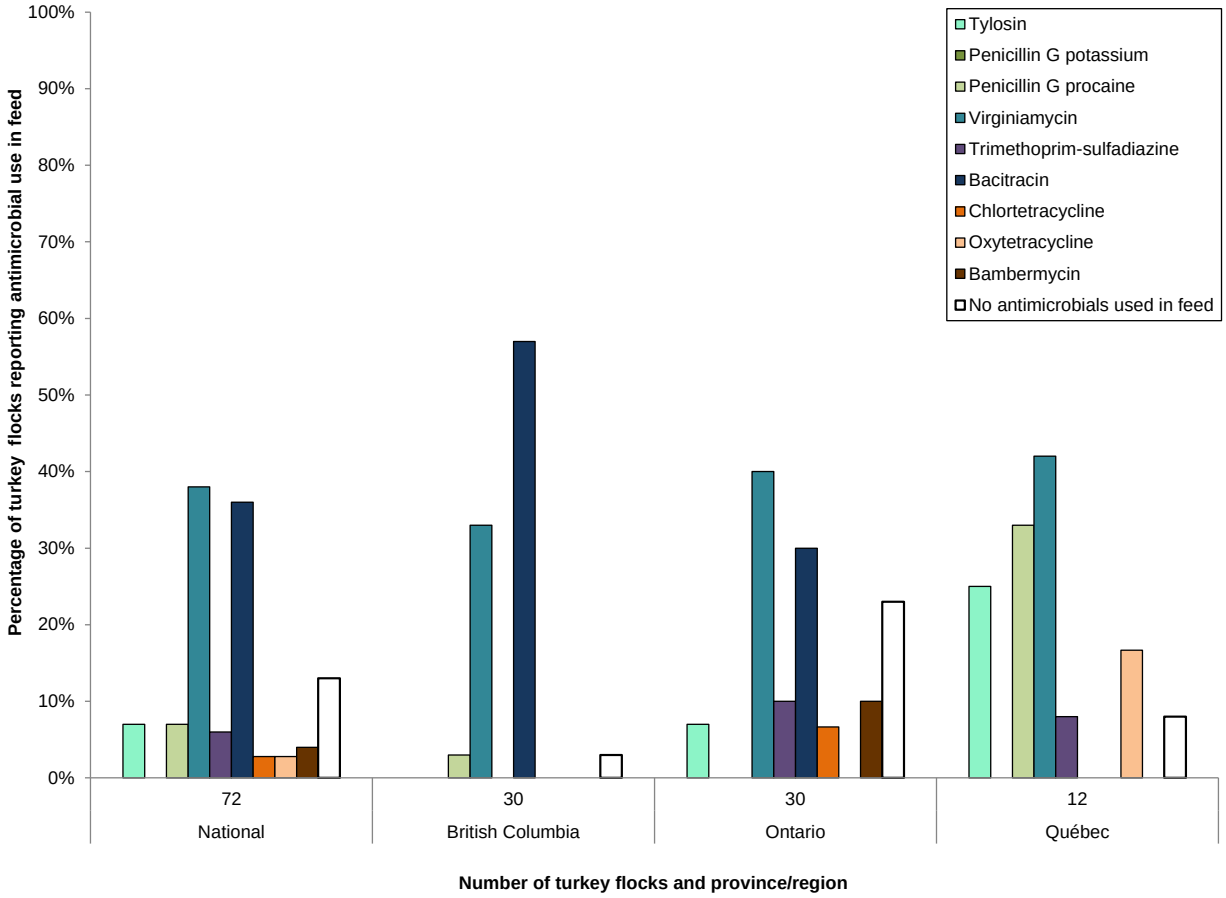
Province/region Number of flocks	National 72	British Columbia 30	Ontario 30	Québec 12
Route of administration				
Feed	59.7	48	86	43
Water	0.6	0	1	0
In ovo or subcutaneous injection	0.1	0.1	0.1	0.1
Total	**60.5**	**49**	**87**	**43**

mg/PCU = milligrams/population correction unit.

For detailed indicator description, please refer to Table 3. 1.

Antimicrobial use in feed by frequency

Figure 3. 49 Percentage of turkey flocks reporting antimicrobial use in feed, 2016



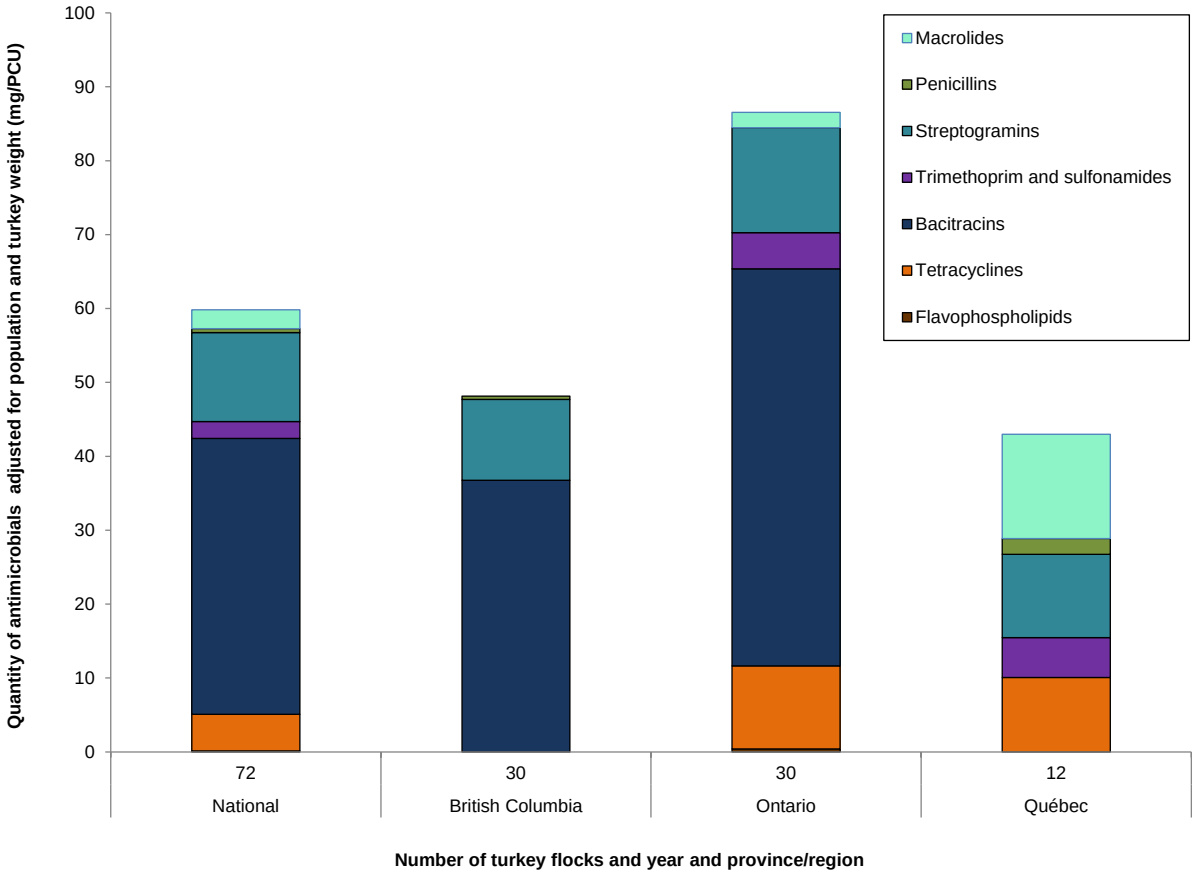
Province/region Number of flocks	National 72	British Columbia 30	Ontario 30	Québec 12
Antimicrobial				
Tylosin	7%	0%	7%	25%
Penicillin G potassium	0%	0%	0%	0%
II Penicillin G procaine	7%	3%	0%	33%
Virginiamycin	38%	33%	40%	42%
Trimethoprim-sulfadiazine	6%	0%	10%	8%
Bacitracin	36%	57%	30%	0%
III Chlortetracycline	3%	0%	7%	0%
Oxytetracycline	3%	0%	0%	17%
IV Bambermycin	4%	0%	10%	0%
No antimicrobials used in feed	13%	3%	23%	8%

Roman numerals II to IV indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

Numbers per column may not add up to 100% as some flocks may have used an antimicrobial more than once or used multiple antimicrobials throughout the grow-out period.

Antimicrobial use in feed by quantitative indicators

Figure 3. 50 Quantity of antimicrobial use in feed adjusted for population and turkey weight (mg/PCU), 2016



Province/region Number of flocks		National 72	British Columbia 30	Ontario 30	Québec 12
Antimicrobial class					
II	Macrolides	3	0	2	14
	Penicillins	1	0.4	0	2
	Streptogramins	12	11	14	11
	Trimethoprim and sulfonamides	2	0	5	5
III	Bacitracins	37	37	54	0
	Tetracyclines	5	0	11	10
IV	Flavophospholipids	0.1	0	0.4	0
Total		**60**	**48**	**86**	**43**

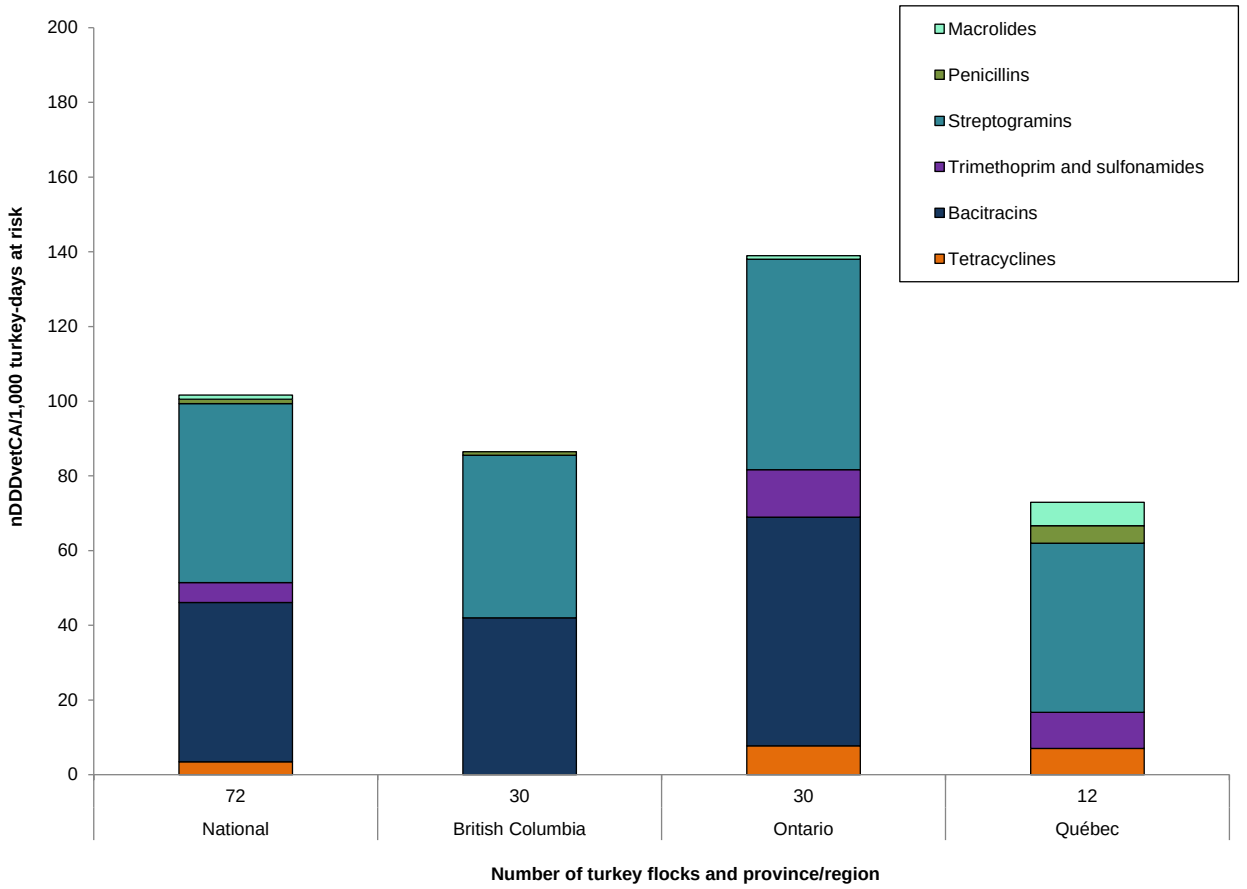
Roman numerals II to IV indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

Flavophospholipids intended for growth promotion and had lower dosing than prevention or treatment dosing was not included in the estimates.

mg/PCU = milligrams/population correction unit.

For detailed indicator description, please refer to Table 3. 1.

Figure 3. 51 Number of Canadian Defined Daily Doses for animals per 1,000 turkey-days at risk (nDDDVetCA/1,000 turkey-days at risk for antimicrobials administered in feed, 2016



Province/region Number of flocks		National 72	British Columbia 30	Ontario 30	Québec 12
Antimicrobial class					
II	Macrolides	1	0	1	6
	Penicillins	1	1	0	5
	Streptogramins	48	44	56	45
	Trimethoprim and sulfonamide	5	0	13	10
III	Bacitracins	43	42	61	0
	Tetracyclines	3	0	8	7
Total		**102**	**86**	**139**	**73**

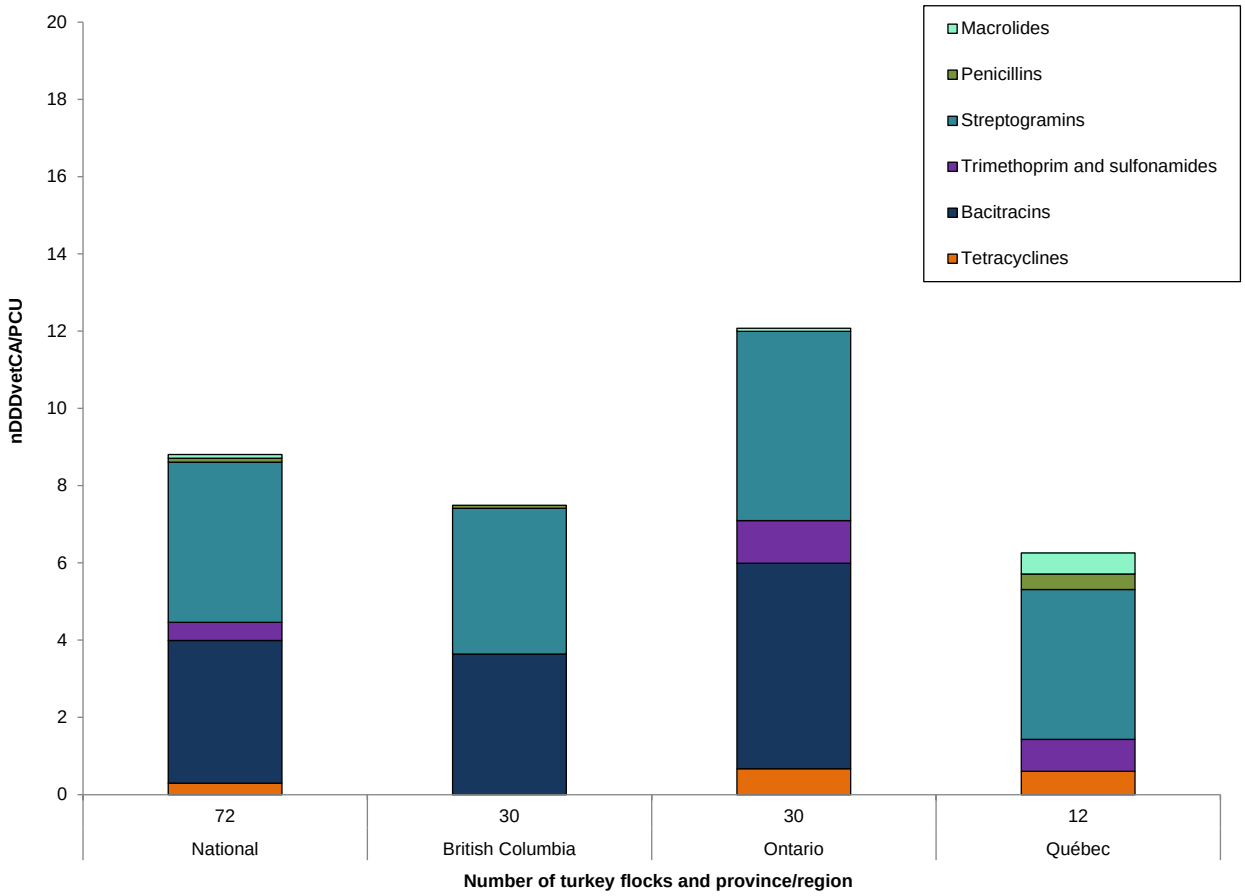
Roman numerals II to III indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

DDDvetCA = Canadian Defined Daily Doses for animals (average labelled dose) in milligram per kilogram turkey weight per day (mg_{drug}/kg_{animal}/day); please refer to Appendix: Supplemental data, Table A. 1 for the list of standards.

nDDDvetCA/1,000 turkey-days at risk = number of DDDvetCA/1,000 turkey-days at risk.

For detailed indicator description, please refer to Table 3. 1.

Figure 3. 52 Number of Canadian Defined Daily Doses for animals per population correction unit (nDDDvetCA/PCU) for antimicrobials adminimistered in feed, 2016



Province/region Number of flocks		National 72	British Columbia 30	Ontario 30	Québec 12
Antimicrobial class					
II	Macrolides	0	0	0.1	1
	Penicillins	0.1	0.1	0	0.4
	Streptogramins	4	4	5	4
	Trimethoprim and sulfonamides	0.5	0	1	1
III	Bacitracins	4	4	5	0
	Tetracyclines	0	0	1	1
Total		**9**	**7**	**12**	**6**

Roman numerals II to III indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

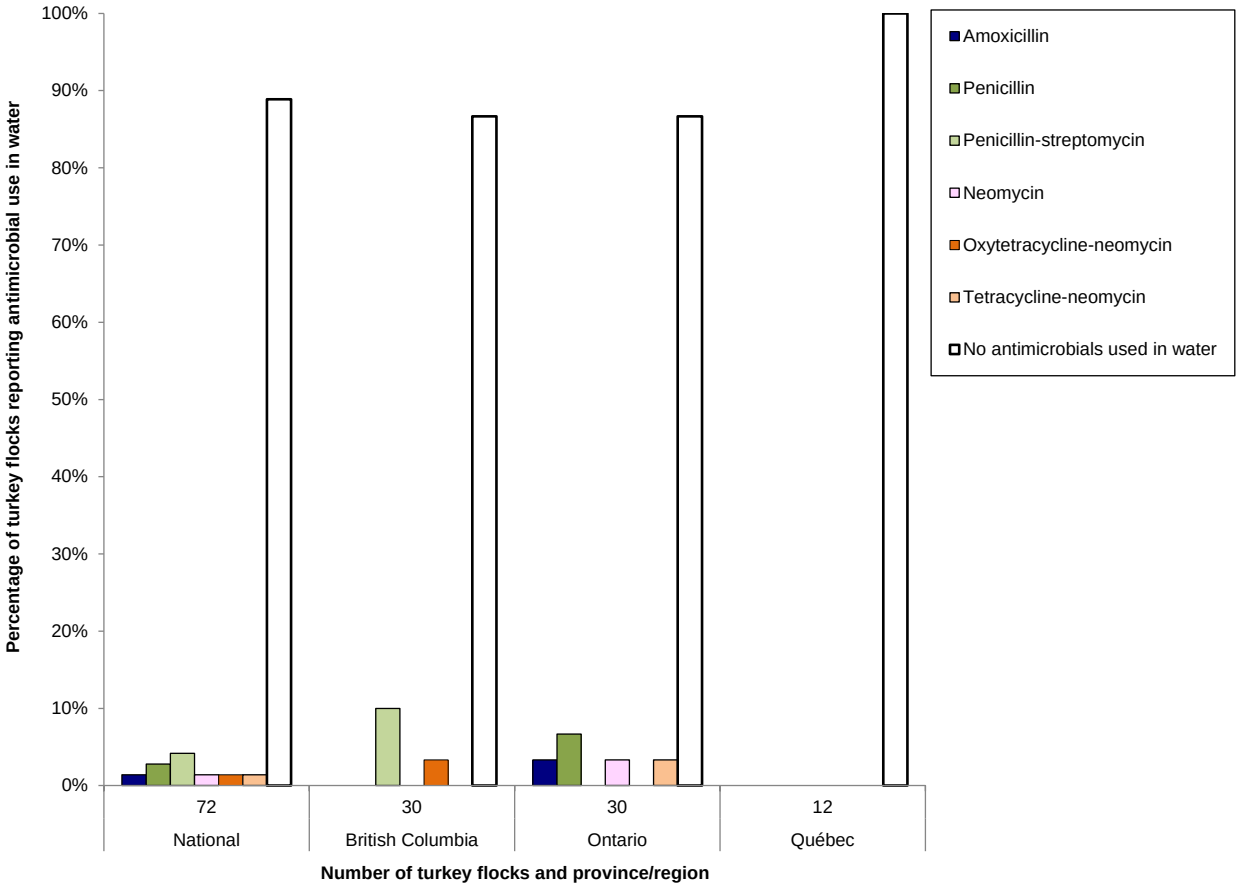
DDDvetCA = Canadian Defined Daily Doses for animals (average labelled dose) in milligram per kilogram turkey weight per day (mg_{drug}/kg_{animal}/day); please refer to Appendix: Supplemental data, Table A. 1 for the list of standards.

nDDDvetCA/PCU = number of DDDvetCA/population correction unit.

For detailed indicator description, please refer to Table 3. 1.

Antimicrobial use in water by frequency

Figure 3. 53 Percentage of turkey flocks reporting antimicrobial use in water, 2016



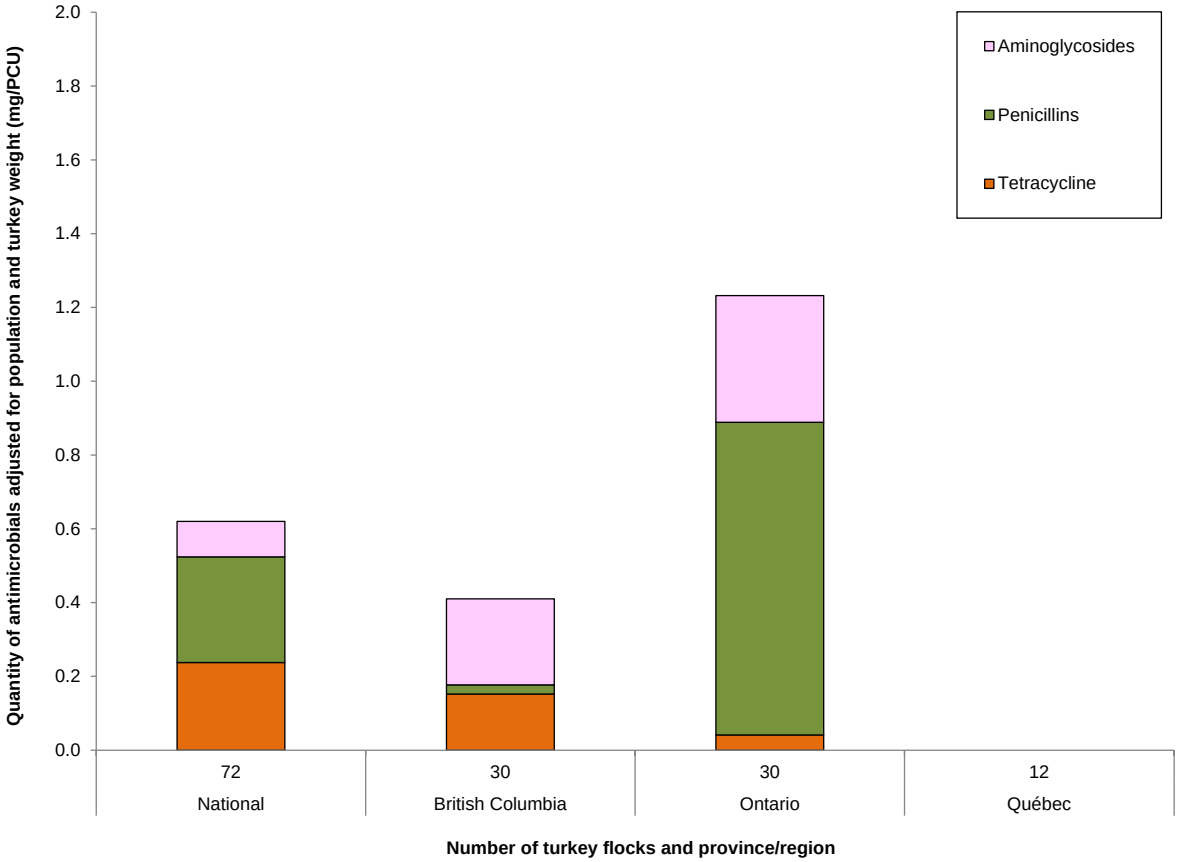
Province/region Number of flocks		National 72	British Columbia 30	Ontario 30	Québec 12
Antimicrobial					
II	Amoxicillin	1%	0%	3%	0%
	Penicillin	3%	0%	7%	0%
	Penicillin-streptomycin	4%	10%	0%	0%
III	Neomycin	1%	0%	3%	0%
	Oxytetracycline-neomycin	1%	3%	0%	0%
	Tetracycline-neomycin	1%	0%	3%	0%
	No antimicrobials used in water	89%	87%	87%	100%

Roman numerals II to III indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

Numbers per column may not add up to 100% as some flocks have used an antimicrobial more than once or used multiple antimicrobials throughout the growing period.

Antimicrobial use in water by quantitative indicators

Figure 3. 54 Quantity of antimicrobial use in water adjusted for population and turkey weight (mg/PCU), 2016



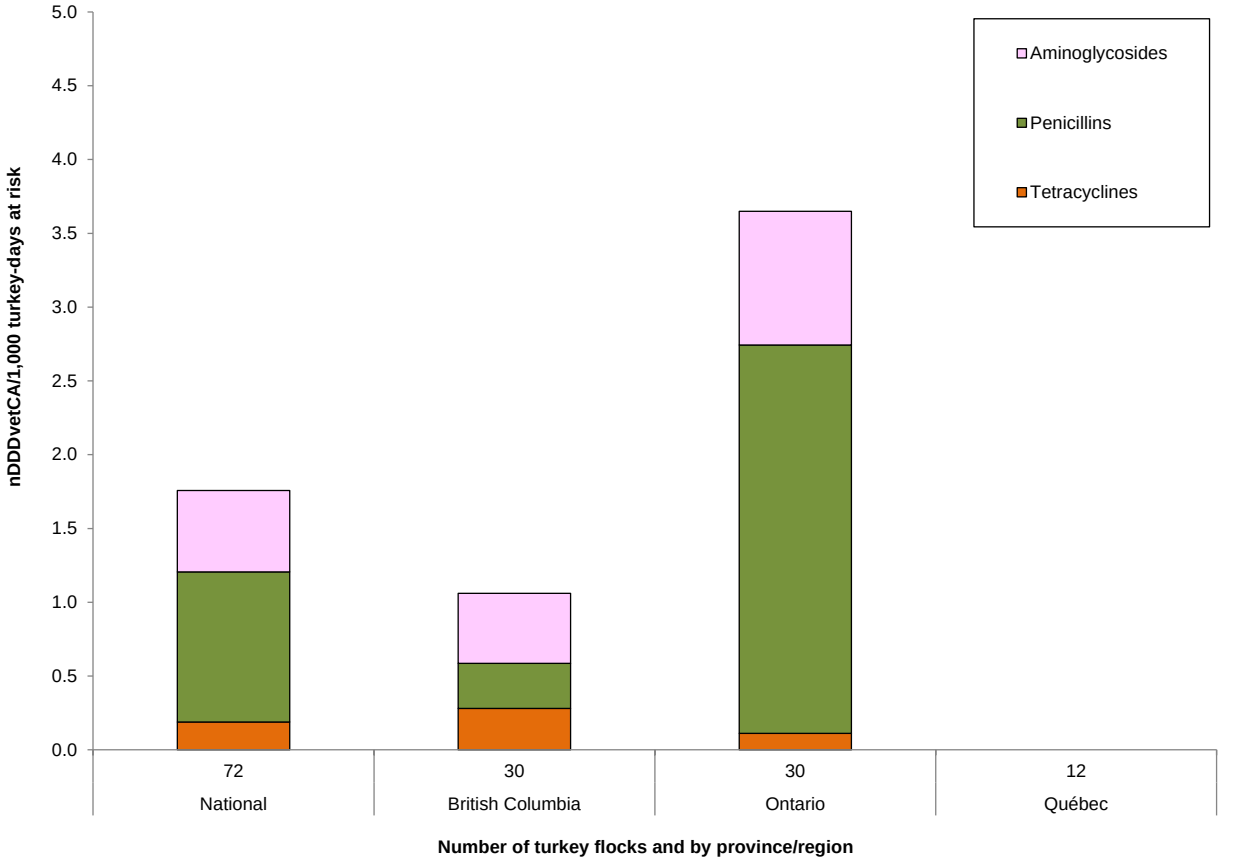
Province/region Number of flocks	National 72	British Columbia 30	Ontario 30	Québec 12
Antimicrobial class				
II Aminoglycosides	0.1	0.2	0.3	0
Penicillins	0.3	< 0.1	1	0
III Tetracyclines	0.2	0.2	< 0.1	0
Total	**0.6**	**0.4**	**1**	**0**

Roman numerals II to III indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

mg/PCU = milligrams/population correction unit

For detailed indicator description, please refer to Table 3. 1.

Figure 3. 55 Number of Canadian Defined Daily Doses for animals per 1,000 turkey-days at risk (nDDDvetCA/1,000 turkey-days at risk) for antimicrobials administered in water, 2016



Province/region Number of flocks	National 72	British Columbia 30	Ontario 30	Québec 12
Antimicrobial class				
II Aminoglycosides	0.6	0.5	0.9	0
Penicillins	1.0	0.3	2.6	0
III Tetracyclines	0.2	0.3	0.1	0
Total	**1.8**	**1.1**	**3.6**	**0**

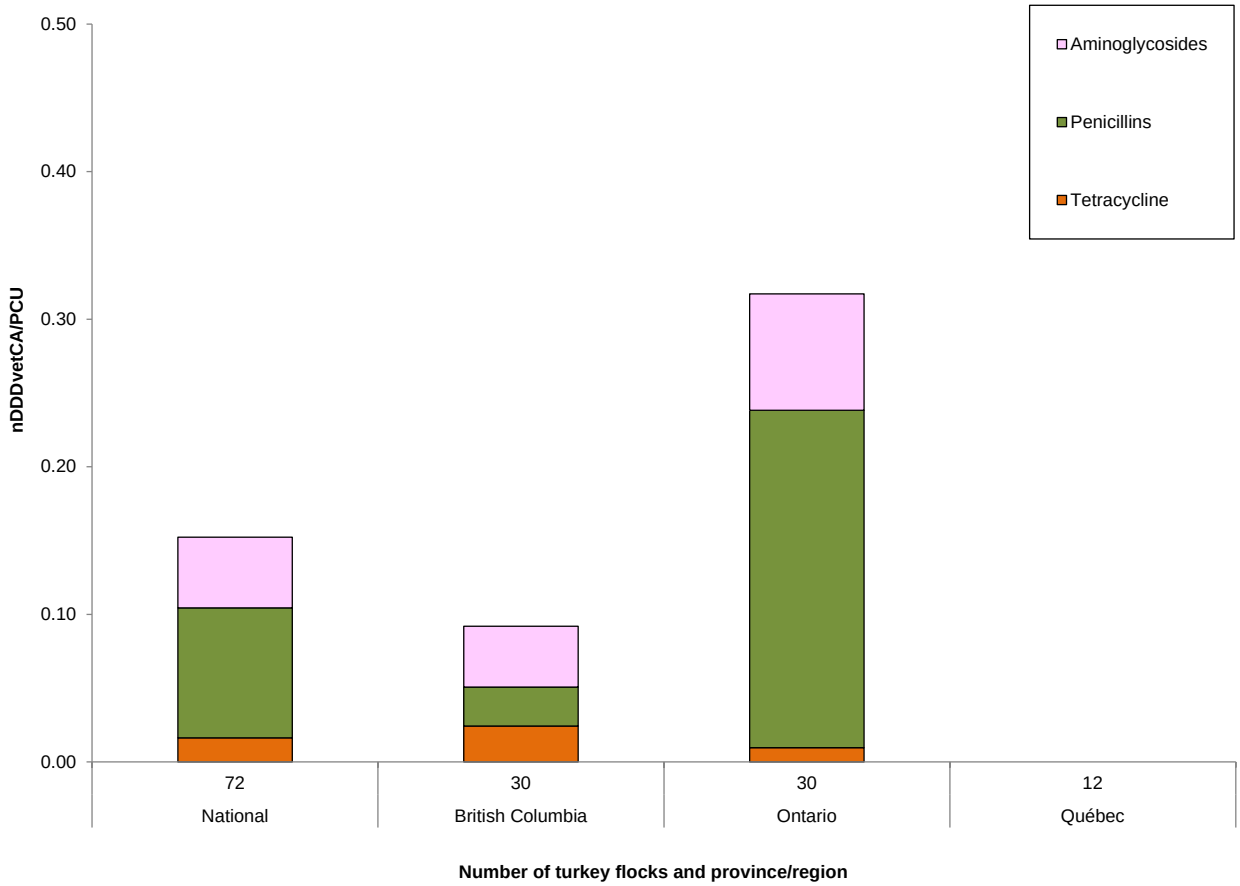
Roman numerals II to III indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

DDDvetCA = Canadian Defined Daily Doses for animals (average labelled dose) in milligram per kilogram turkey weight per day (mg_{drug}/kg_{animal}/day); please refer to Appendix: Supplemental data, Table A. 1 for the list of standards.

nDDDvetCA/1,000 turkey-days at risk = number of DDDvetCA/1,000 turkey-days at risk.

For detailed indicator description, please refer to Table 3. 1.

Figure 3. 56 Number of Canadian Defined Daily Doses for animals per population correction unit (nDDDvetCA/PCU) for antimicrobials administered in water, 2016



Province/region Number of flocks		National 72	British Columbia 30	Ontario 30	Québec 12
Antimicrobial class					
II	Aminoglycosides	0.05	0.04	0.08	0
	Penicillins	0.09	0.03	0.23	0
III	Tetracyclines	0.02	0.02	0.01	0
Total		0.15	**0.09**	**0.32**	**0**

Roman numerals II to III indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

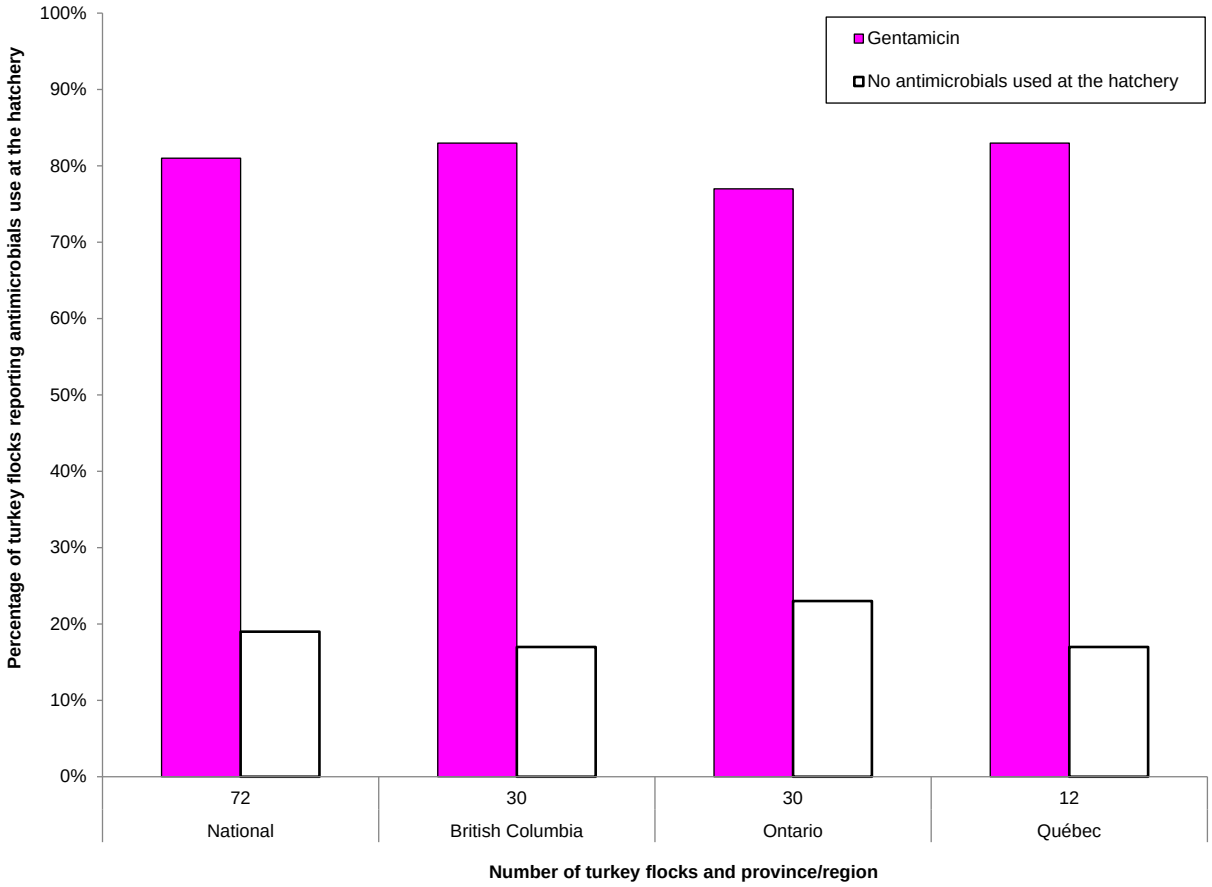
DDDvetCA = Canadian Defined Daily Doses for animals (average labelled dose) in milligram per kilogram turkey weight per day (mg_{drug}/kg_{animal}/day); please refer to Appendix: Supplemental data, Table A. 1 for the list of standards.

nDDDvetCA/PCU = number of DDDvetCA/population correction unit.

For detailed indicator description, please refer to Table 3. 1.

Antimicrobials use *in ovo* or subcutaneous injection by frequency

Figure 3. 57 Percentage of turkey flocks reporting antimicrobial use *in ovo* or subcutaneous injection, 2016

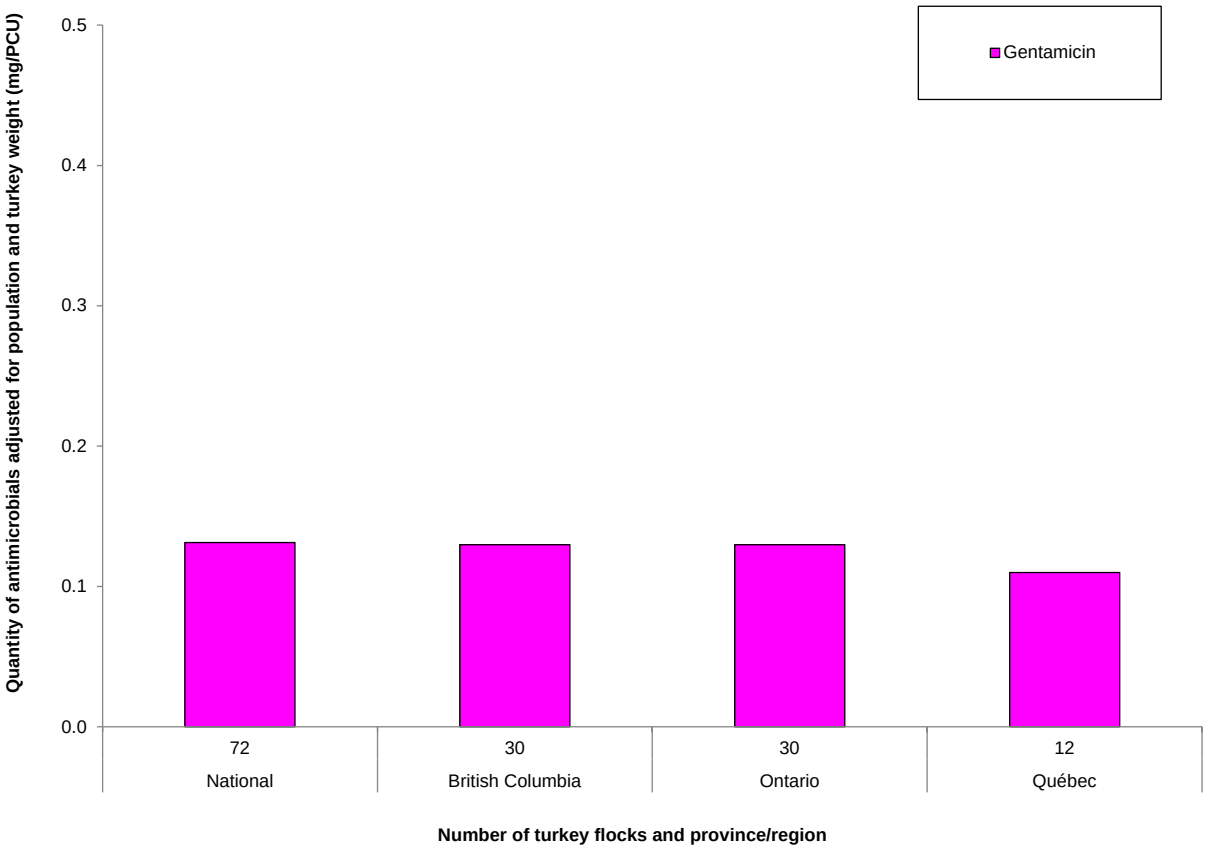


Province/region Number of flocks	National 72	British Columbia 30	Ontario 30	Québec 12
Antimicrobial				
II Gentamicin	81%	83%	77%	83%
No antimicrobials used at the hatchery	19%	17%	23%	17%

Roman numeral II indicates category of importance to human medicine as outlined by the Veterinary Drugs Directorate.

Numbers per column may not add up to 100% due to rounding and a batch of poults (hatched at the same time to supply 1 barn) that may have used 2 antimicrobials.

Figure 3. 58 Quantity of antimicrobial use *in ovo* or subcutaneous injection adjusted for population and turkey weight (mg/PCU), 2016



Province/region Number of flocks	National 72	British Columbia 30	Ontario 30	Québec 12
Antimicrobial				
II Gentamicin	0.13	0.13	0.13	0.11
Total	**0.13**	**0.13**	**0.13**	**0.11**

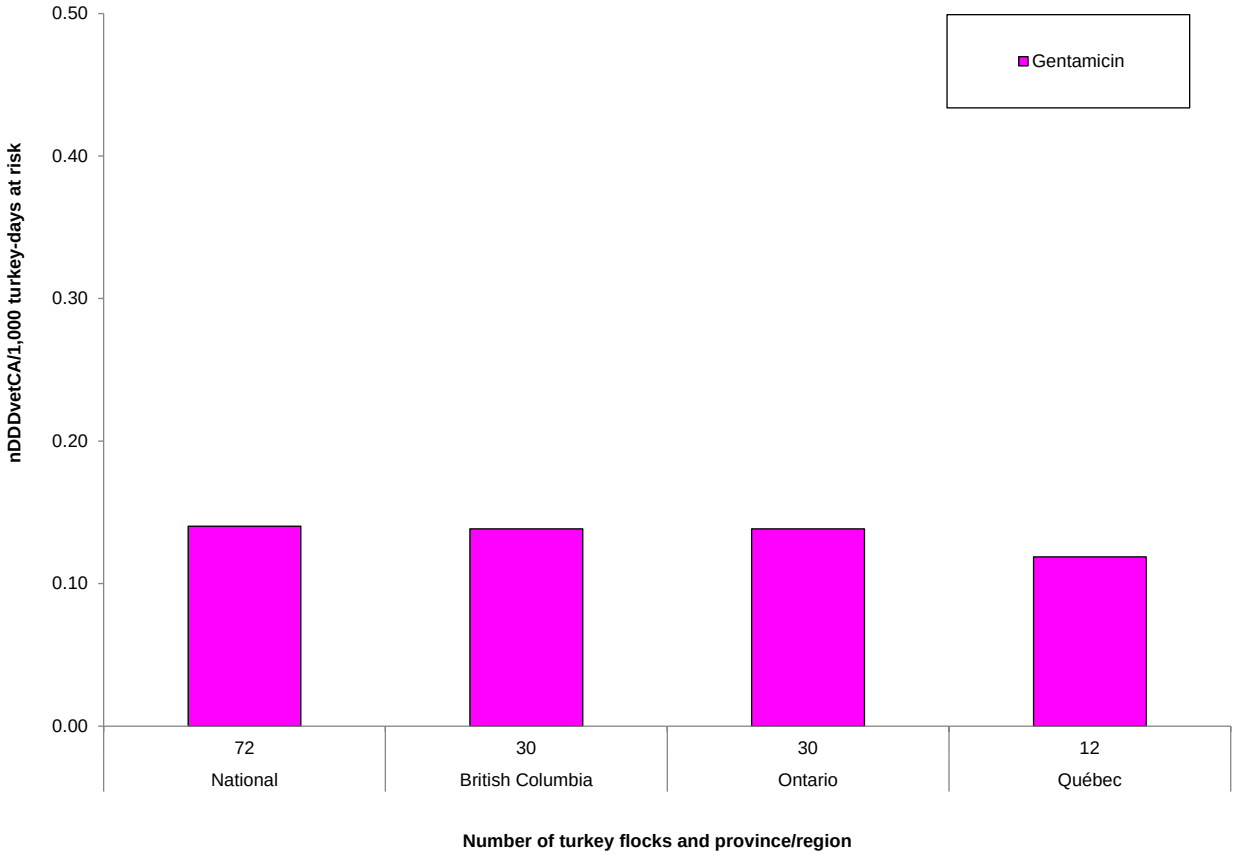
Roman numeral II indicates category of importance to human medicine as outlined by the Veterinary Drugs Directorate.

Total milligrams active ingredient was calculated using the final dose (in milligrams per hatching egg or poult) suggested by the manufacturer and expert opinion based on milligrams per body weight or residue avoidance information: gentamicin routine dose (1 mg/poult).

mg/PCU = milligrams/population correction unit.

For detailed indicator description, please refer to Table 3. 1.

Figure 3. 59 Number of Canadian Defined Daily Doses for animals per 1,000 turkey-days at risk (nDDDvetCA/1,000 turkey-days at risk) for antimicrobials administered *in ovo* or subcutaneous injection, 2016



Province/region Number of flocks	National 72	British Columbia 30	Ontario 30	Québec 12
Antimicrobial				
II Gentamicin	0.14	0.14	0.14	0.12
Total	**0.14**	**0.14**	**0.14**	**0.12**

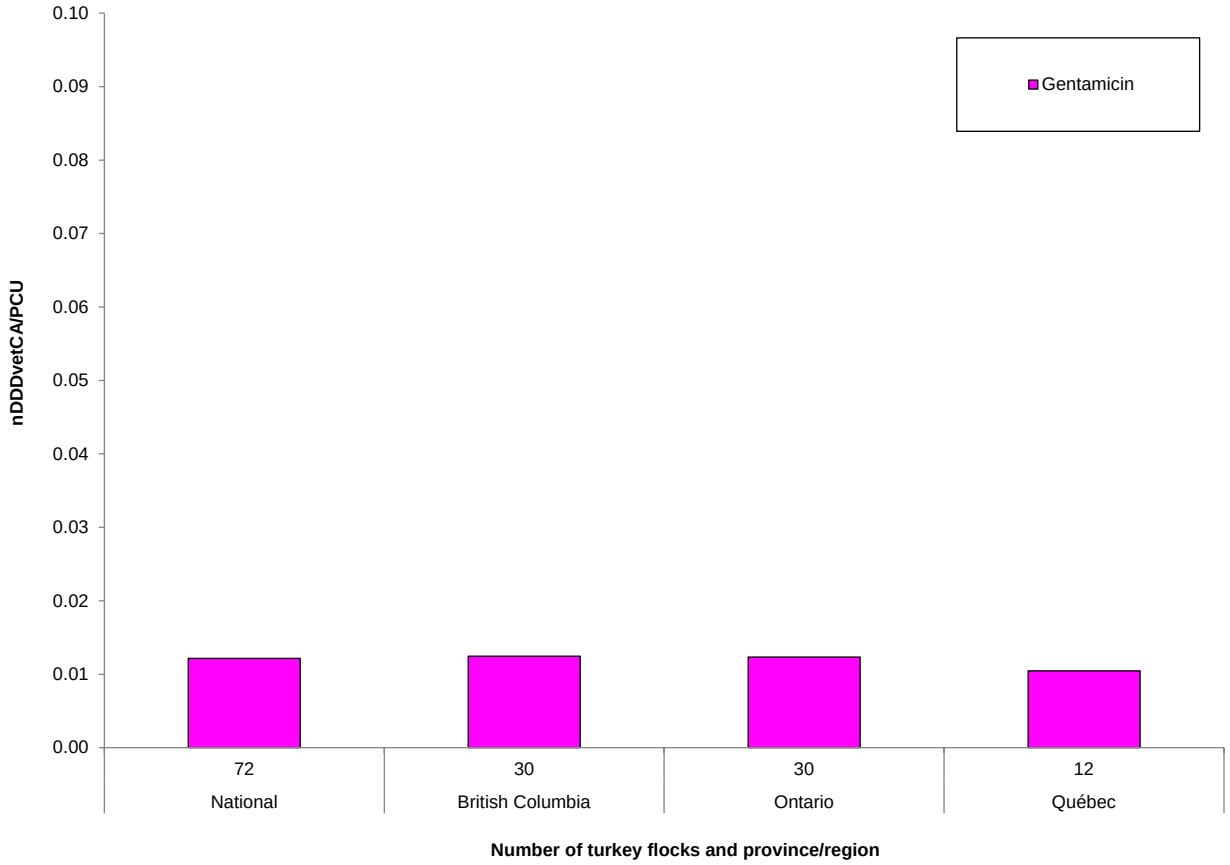
Roman numeral II indicates category of importance to human medicine as outlined by the Veterinary Drugs Directorate.

DDDvetCA = Canadian Defined Daily Doses for animals (average labelled dose) in milligram per kilogram turkey weight per day (mg_{drug}/kg_{animal}/day); please refer to Appendix: Supplemental data, Table A. 1 for the list of standards.

nDDDvetCA/1,000 turkey-days at risk = number of DDDvetCA/1,000 turkey-days at risk.

For detailed indicator description, please refer to Table 3. 1.

Figure 3. 60 Number of Canadian Defined Daily Doses for animals per population correction unit (nDDDvetCA/PCU) for antimicrobials administered *in ovo* or subcutaneous injection, 2016



Province/region Number of flocks	National 72	British Columbia 30	Ontario 30	Québec 12
Antimicrobial				
II Gentamicin	0.01	0.01	0.01	0.01
Total	**0.01**	**0.01**	**0.01**	**0.01**

Roman numerals II to III indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

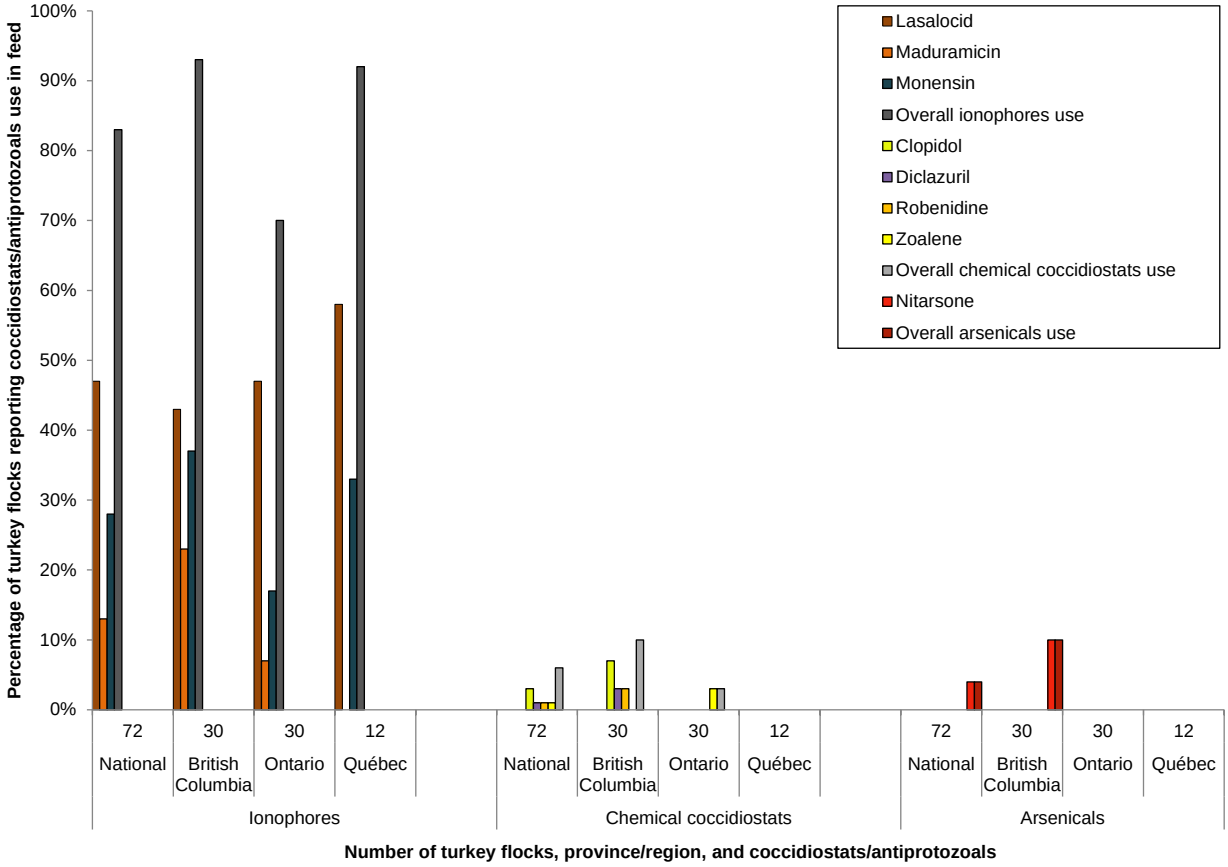
DDDvetCA = Canadian Defined Daily Doses for animals (average labelled dose) in milligram per kilogram turkey weight per day (mg_{drug}/kg_{animal}/day); please refer to Appendix: Supplemental data, Table A. 1 for the list of standards.

nDDDvetCA/PCU = number of DDDvetCA/population correction unit.

For detailed indicator description, please refer to Table 3. 1.

Coccidiostat and antiprotozoal use in feed by frequency

Figure 3. 61 Percentage of turkey flocks reporting coccidiostat and other antiprotozoals use in feed, 2016



Province/region Number of flocks		National 72	British Columbia 30	Ontario 30	Québec 12
Coccidiostat					
IV	Lasalocid	47%	43%	47%	58%
	Maduramicin	13%	23%	7%	0%
	Monensin	28%	37%	17%	33%
	Overall ionophores use	**83%**	**93%**	**70%**	**92%**
N/A	Clopidol	3%	7%	0%	0%
	Diclazuril	1%	3%	0%	0%
	Robenidine	1%	3%	0%	0%
	Zoalene	1%	0%	3%	0%
	Overall chemical coccidiostats use	**6%**	**10%**	**3%**	**0%**
	Nitarsone	4%	10%	0%	0%
	Overall arsenicals use	**4%**	**10%**	**0%**	**0%**

Roman numeral IV indicates category of importance to human medicine as outlined by the Veterinary Drugs Directorate. N/A = not applicable (no classification at the time of writing of this report).

Chapter 4 Antimicrobial resistance

Human Surveillance

Key findings

The Provincial Public Health Laboratories forwarded a total of 2,567 *Salmonella* isolates that underwent susceptibility testing at the National Microbiology Laboratory, Public Health Agency of Canada.

Salmonella (n = 2,567)

Susceptibility testing was routinely carried out on 8 serovars: Enteritidis, Heidelberg, 4,[5],12:i:-, Newport, Paratyphi A, Paratyphi B, Typhi, and Typhimurium (2,305 isolates). In addition, 262 isolates of other *Salmonella* serovars were also tested.

The most commonly isolated serovars in 2016 were Enteritidis (45%, 1,165/2,567), Typhimurium (13%, 323/2,567) and Heidelberg (12%, 315/2,567) (Table 4. 1).

Eleven percent (275/2,567) of isolates were recovered from blood. Typhoidal isolates (Typhi, Paratyphi A, and Paratyphi B) accounted for a large proportion of these isolates from blood (44%, 120/275). Recovery from urine occurred for 99 of 2,567 isolates (4%). In contrast to isolation from blood, typhoidal isolates accounted for a very small proportion of isolates from urine (1%, 1/99). The proportion of isolates recovered from blood, urine, and other sample types varied by serovar (Figure 4. 1).

Non-typhoidal *Salmonella* (n = 2,405)

In 2016, 67% (1,616/2,405) of all non-typhoidal *Salmonella* isolates were susceptible to all antimicrobial classes tested, compared to 74% in 2015. Eighteen percent (440/2,405) of isolates were resistant to a single antimicrobial. Resistance to nalidixic acid increased in 2016 (16%, 385/2,405) compared to 2015 (11%, 260/2,360). Additionally, resistance to ceftriaxone dropped to 4% (96/2,405) in 2016, the lowest level observed since 2009. (Figure 4. 2).

Typhoidal *Salmonella* (n = 162)[63]

In 2016, a total of 86% (140/162) of isolates were resistant to 1 or more antimicrobials tested. Sixty-four percent (104/162) of isolates were resistant to a single antimicrobial. A high proportion (84%; 136/162) of typhoidal isolates were resistant to nalidixic acid and 14% (23/162) were resistant to ciprofloxacin.

Resistance to nalidixic acid increased in 2016 to 84% (136/162) compared to 76% (123/162) in 2015 (Figure 4. 3).

[63] *Salmonella* Paratyphi B does not include *S*. Paratyphi B var. L (+) tartrate (+), formerly called *S*. Paratyphi var. Java. The biotype of *S*. Paratyphi B included here is tartrate (-) and associated with severe typhoid-like fever. *Salmonella* Paratyphi B var. L (+) tartrate (+) is commonly associated with gastrointestinal illness.

Enteritidis (n = 1,165)

In 2016, 5% of Enteritidis isolates were recovered from blood (62/1,165) and 3% of isolates were recovered from urine (34/1,165) (Figure 4. 1).

Thirty-one percent (359/1,165) of Enteritidis isolates in 2016 were resistant to 1 or more antimicrobial class tested. The most common resistance was to nalidixic acid; 27% (317/1,165) of isolates were resistant to this antimicrobial (Table 4. 1).

Resistance to nalidixic acid increased in 2016 (27%, 317/1,165) over 2015 (17%, 202/1,188) (Figure 4. 4). Similarly, resistance to ciprofloxacin increased to 2% (20/1,165) in 2016 over less than 1% in 2015 (data not shown).

Heidelberg (n = 315)

In 2016, 17% of Heidelberg isolates were recovered from blood (54/315) and 6% of isolates were recovered from urine (20/315) (Figure 4. 1).

Sixteen percent (49/315) of Heidelberg isolates were resistant to ceftriaxone (Table 4. 1).

Resistance to ampicillin, ceftriaxone, and streptomycin decreased in 2016 (19%, 61/315; 16%, 49/315; and 27%, 85/315, respectively) over 2015 (33%, 101/307; 27%, 83/307; and 32%, 98/307, respectively) (Figure 4. 5).

Newport (n = 185)

Two percent (3/185) of Newport isolates were recovered from blood in 2016 and 4% from urine (7/185) (Figure 4. 1).

Ten percent (19/185) of the Newport isolates were resistant to 1 or more antimicrobial classes tested (Table 4. 1). Resistance to tetracycline increased in 2016 (9%, 17/185) compared to 2015 (5%, 11/229) (Figure 4. 6).

One Newport isolate (less than 1%) was resistant to 6 antimicrobial classes (all classes tested except the quinolones). This isolate was recovered from a stool sample collected from a female aged 30 to 49 from Saskatchewan (PT14b).

Paratyphi A and Paratyphi B (n = 25)[64]

Seventy-six percent (19/25) of Paratyphi A and B isolates were recovered from blood samples and none from urine (Figure 4. 1).

Most (88%; 22/25) Paratyphi A and B isolates were resistant to nalidixic acid (Table 4. 1). Resistance to nalidixic acid increased to 88% (22/25) in 2016 compared to 69% (25/36) in 2015 and resistance to streptomycin deceased to 0% in 2016 (0/25) compared to 17% in 2015 (6/36) (Figure 4. 7).

[64] *Salmonella* Paratyphi B does not include *S*. Paratyphi B var. L (+) tartrate (+), formerly called *S*. Paratyphi var. Java. The biotype of *S*. Paratyphi B included here is tartrate (-) and associated with severe typhoid-like fever. *Salmonella* Paratyphi B var. L (+) tartrate (+) is commonly associated with gastrointestinal illness. However, there were no Paratyphi B isolates received for susceptibility testing in 2012.

Typhi (n = 137)

Seventy-four percent (101/137) of isolates were recovered from blood samples in 2016. Recovery of Typhi from urine remained low in 2016 (1%, 1/137) (Figure 4. 1).

Resistance to nalidixic acid was observed in 83% (114/137) of isolates (Table 4. 1). Resistance to nalidixic acid in 2015 was 78% (98/126) (Figure 4. 8).

One Typhi isolate (1%) was resistant to 6 antimicrobial classes (all classes tested except the macrolides). This isolate was recovered from a stool sample collected from a male (unknown age) from British Columbia (PT E1).

Typhimurium (n = 323)

Four percent (13/323) of Typhimurium isolates in 2016 were recovered from blood samples and 2% (8/323) from urine (Figure 4. 1).

Thirteen Typhimurium isolates (4%, 13/323) were resistant to 6 antimicrobial classes; 11 were resistant to all classes tested except the macrolides (3%, 11/323) and 2 were resistant to all classes except the quinolones (1%, 2/323) (Table 4. 1). Nine of the isolates resistant to 6 classes were recovered from the Atlantic provinces (New Brunswick and Nova Scotia), all cases were male and all but 1 were aged over 70 years. The isolates from this region were various phage types and from various sources (2 from blood, 4 from stool, 1 from urine and 2 from an unknown source). In addition, 38 Typhimurium isolates (12%, 38/323) were resistant to 5 antimicrobial classes. Among all 51 isolates (16%, 51/323) resistant to 5 or more antimicrobial classes, all but 2 contained the ACSSuT pattern.

Resistance to streptomycin decreased in 2016 (27%, 87/323) compared to 2015 (31%, 91/294) (Figure 4. 9).

4,[5],12:i:- (n = 155)

Four percent (6/155) of isolates were recovered from blood samples in 2016 and 4% (6/155) from urine (Figure 4. 1).

Resistance to ampicillin and gentamicin increased in 2016 (55%, 85/155 and 10%, 15/155 respectively) compared to 2015 (51%, 71/140 and 4%, 6/140 respectively). There has also been an increasing trend in resistance to ampicillin, streptomycin and tetracycline, most noticeable since 2011 (Figure 4. 10).

One 4,[5].12:i:- isolate (1%) was resistant to 7 antimicrobial classes (all antimicrobial classes tested). This isolate was recovered from a stool sample collected from a male aged 18 to 29 years from Ontario (PT 193). Four other 4,[5].12:i:- isolates (3%, 4/155) were resistant to 6 antimicrobial classes (3 isolates were resistant to all classes tested except the macrolides and 1 was resistant to all classes except the quinolones). All isolates were recovered from stool samples, 3 were from Ontario and 1 was from British Columbia.

Other non-typhoidal serovars (n = 262)

Among the other non-typhoidal *Salmonella* serovars tested by CIPARS in 2016, the most common were Infantis (n = 211), Dublin (n = 15) and Kentucky (n = 12) (data not shown).

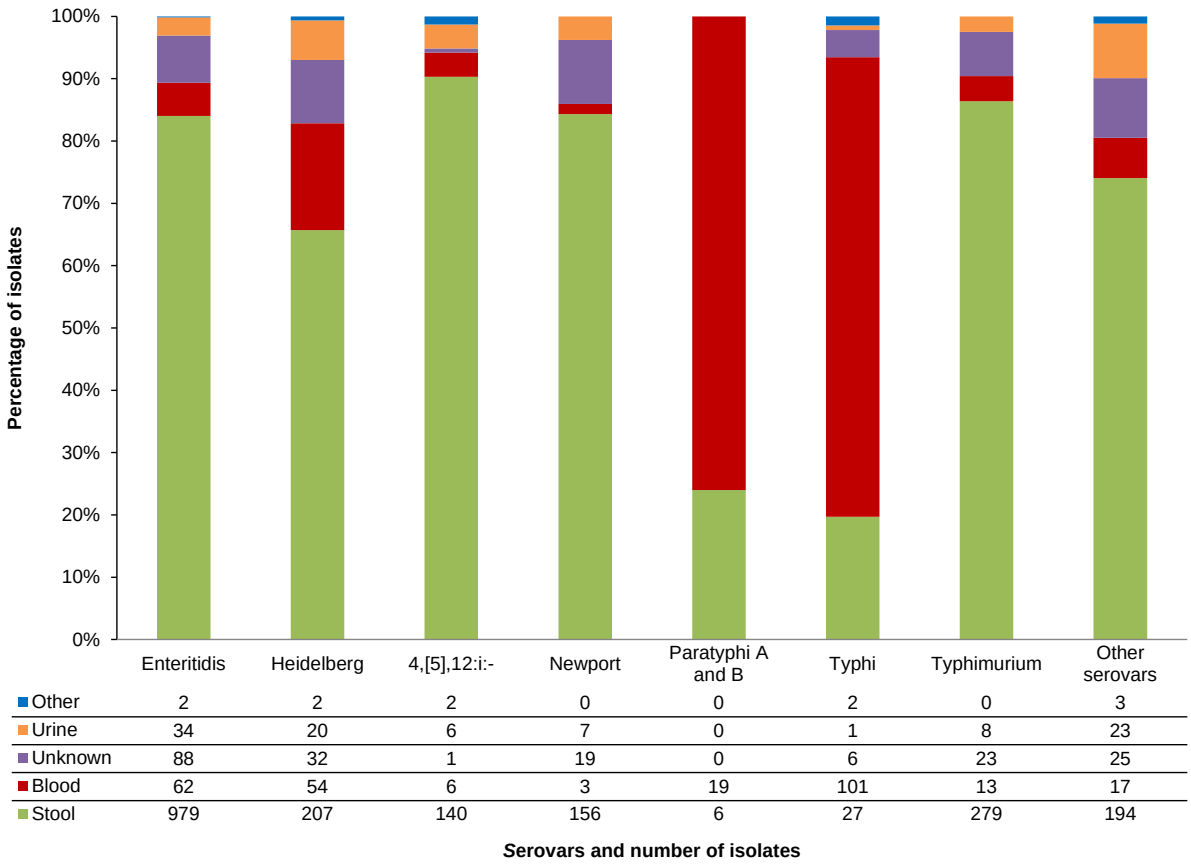
Seven of the Infantis isolates (3%, 7/211) were resistant to 6 antimicrobial classes (all except the macrolides). All of these multidrug resistant (MDR) isolates were recovered from stool but overall, 2% (5/211) of Infantis isolates were recovered from blood.

Six Dublin isolates (40%, 6/15) were resistant to 6 antimicrobial classes tested, all except the macrolides. All of these MDR isolates except 1 were recovered from blood; 4 isolates were from Québec and 2 were from Ontario. Seventy-three percent (11/15) of Dublin isolates were recovered from blood, none were recovered from urine.

Six Kentucky isolates (50%, 6/12) were resistant to 5 antimicrobial classes, all except the macrolides and phenicols. No Kentucky isolates from humans were resistant to ceftriaxone or amoxicillin-clavulanic acid.

Serovar distribution

Figure 4. 1 Proportion of human *Salmonella* serovars from all sample sources, 2016



Salmonella Paratyphi B does not include *S*. Paratyphi B var. L (+) tartrate (+), formerly called *S*. Paratyphi var. Java. The biotype of *S*. Paratyphi B included here is tartrate (-) and associated with severe typhoid-like fever. *Salmonella* Paratyphi B var. L (+) tartrate (+) is commonly associated with gastrointestinal illness.

Multiclass resistance

Table 4. 1 Number of antimicrobial classes in resistance patterns of *Salmonella* serovars, 2016

Province or region/serovar	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial												
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
British Columbia																				
Enteritidis	127 (55.5)	112	8	5	2		1	2	6		1			2	1		1		12	3
Other serovars	27 (11.8)	20		2	5		2	3	5					5	1		1	5	6	7
Typhi	16 (7.0)	1	11	1	2	1		4	2			1		3	3		2	4	15	2
Typhimurium	16 (7.0)	6		3	6	1		10	7	1	1	1		10			4		2	7
Newport	14 (6.1)	14																		
4,[5],12:i:-	11 (4.8)	1		2	7	1	1	10	8	1	1	1		10		1	1		1	8
Heidelberg	11 (4.8)	6	5					1	4	4	4	4								
Paratyphi A and B	7 (3.1)		7															1	7	
Total	**229 (100)**	**160**	**31**	**13**	**22**	**3**	**4**	**30**	**32**	**6**	**7**	**7**		**30**	**5**	**1**	**9**	**10**	**43**	**27**
Alberta																				
Enteritidis	151 (50.2)	131	16	4			1	1	3					1	1			1	17	3
Typhimurium	34 (11.3)	16	2	5	10	1		16	11	1				15	1	2	3		1	12
Other serovars	28 (9.3)	21	2	3	2		1	4	2	1	1	1		3	1		2	2	3	4
Heidelberg	25 (8.3)	15	8	1	1		1	5	6	4	4	4		1	1		1			1
4,[5],12:i:-	23 (7.6)	9	4	1	9		1	9	10		1			9	1		2		2	14
Newport	20 (6.6)	17			3			3	2	2	2	2		3	1		3			3
Typhi	19 (6.3)	2	12	1	4			6	4					4	4		4	5	16	
Paratyphi A and B	1 (0.3)		1																1	
Total	**301 (100)**	**211**	**45**	**15**	**29**	**1**	**4**	**44**	**38**	**8**	**8**	**7**		**36**	**10**	**2**	**15**	**8**	**40**	**37**
Saskatchewan																				
Enteritidis	128 (68.1)	103	22	2	1			1	3					2	2				23	1
Typhimurium	20 (10.6)	17	1		2			2	3					2			1			2
4,[5],12:i:-	9 (4.8)		2	1	6		1	7	7		1			7	1		1			8
Heidelberg	9 (4.8)	4	1	2	2		2	5	2	2	2	2		4						3
Newport	9 (4.8)	6	1		1	1	1	2	3					2	1	1	1			2
Other serovars	9 (4.8)	7	1			1		1	2	1	2	1		1	1		1		1	1
Typhi	3 (1.6)				3			3	3					3	3		3		3	
Paratyphi A and B	1 (0.5)		1																1	
Total	**188 (100)**	**137**	**29**	**5**	**15**		**4**	**21**	**23**	**3**	**5**	**3**		**21**	**8**	**1**	**7**		**28**	**17**
Manitoba																				
Enteritidis	101 (45.7)	67	30	2	2				5					3	3			1	27	7
Other serovars	32 (14.5)	29	1		2		1	2	2	1		1		2	1	1	1	1	1	2
Heidelberg	31 (14.0)	21	9		1		1	9	2	2	2	2		1			1			1
Typhimurium	21 (9.5)	12		4	5			6	7	2				9			5			7
Newport	20 (9.0)	20																		
4,[5],12:i:-	11 (5.0)	2	1	1	7		4	7	8					7						9
Typhi	5 (2.3)	1	4															2	4	
Total	**221 (100)**	**152**	**45**	**7**	**17**		**6**	**24**	**24**	**5**	**2**	**3**		**22**	**4**	**1**	**7**	**4**	**32**	**26**
Ontario																				
Enteritidis	301 (33.2)	177	108	11	5			6	11	1	2	1		11	7		2	6	107	15
Typhimurium	130 (14.3)	94	7	8	19	2	2	23	21	1				28	7	2	19	2	4	30
Heidelberg	120 (13.2)	68	30	19	3		14	32	24	17	18	16		14	2	1	3		3	8
Other serovars	105 (11.6)	88	4		8	5	2	11	12	5	8	5		12	7		9	2	12	14
Newport	95 (10.5)	86		2	7		2	7	5	3	2	2		8	5	1	5		3	8
Typhi	76 (8.4)	9	47	4	16			19	15					17	17		17	6	65	2
4,[5],12:i:-	67 (7.4)	29	3	9	22	4	7	33	33	2	3	2		34	6	2	6	3	4	30
Paratyphi A and B	12 (1.3)	2	10															2	10	
Total	**906 (100)**	**553**	**209**	**53**	**80**	**11**	**27**	**131**	**121**	**29**	**33**	**26**		**124**	**51**	**6**	**61**	**21**	**208**	**107**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

Salmonella Paratyphi B does not include *S*. Paratyphi B var. L (+) tartrate (+), formerly called *S*. Paratyphi var. Java. The biotype of *S*. Paratyphi B included here is tartrate (-) and associated with severe typhoid-like fever. *Salmonella* Paratyphi B var. L (+) tartrate (+) is commonly associated with gastrointestinal illness.

Table 4. 1 Number of antimicrobial classes in resistance patterns of *Salmonella* serovars, 2016 (continued)

Province or region/serovar	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial												
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
Québec																				
Enteritidis	169 (42.3)	101	64		4			3	3					4	1			5	66	4
Heidelberg	69 (17.3)	44	16	8	1		5	17	11	6	7	6		6	2		1		1	1
Typhimurium	56 (14.0)	35	6	3	12		1	14	15	1	3	1		15	3	1	11			15
Other serovars	39 (9.8)	23		2	8	6	4	14	11	6	8	6		14	2		11	2	12	16
4,[5],12:i:-	26 (6.5)	7	3	5	11		1	15	13					15			1			16
Newport	21 (5.3)	19		1	1			1	1	1	1	1		2			1		1	2
Typhi	16 (4.0)	6	6	1	3			5	3					3	3		3	1	9	
Paratyphi A and B	4 (1.0)	1	3															2	3	
Total	**400 (100)**	**236**	**98**	**20**	**40**	**6**	**11**	**69**	**57**	**14**	**19**	**14**		**59**	**11**	**1**	**28**	**10**	**92**	**54**
New Brunswick																				
Enteritidis	71 (55.9)	45	23	2	1			1	2					2	2			1	22	4
Typhimurium	24 (18.9)	13		4	1	6		7	8		5			10	5		7	4	6	11
Heidelberg	21 (16.5)	17	4						4	4	4	4								
Other serovars	8 (6.3)	6	1			1		2	1		1			1	1		1		1	1
Newport	2 (1.6)	1	1																	1
4,[5],12:i:-	1 (0.8)	1																		
Total	**127 (100)**	**83**	**29**	**6**	**2**	**7**		**10**	**15**	**4**	**10**	**4**		**13**	**8**		**8**	**5**	**29**	**17**
Nova Scotia																				
Enteritidis	77 (63.1)	44	26	6	1		1	1	6					2	3			5	29	5
Heidelberg	18 (14.8)	5	10	3			2	10	4	4	4	4		2	1					
Typhimurium	16 (13.1)	5	3	2	3	3		8	7	1	2	1		8	2		5		3	8
Other serovars	5 (4.1)	5																		
4,[5],12:i:-	4 (3.3)	1			3			3	3					3						3
Typhi	2 (1.6)		2																2	
Total	**122 (100)**	**60**	**41**	**11**	**7**		**3**	**22**	**20**	**5**	**6**	**5**		**15**	**6**		**5**	**5**	**34**	**16**
Prince Edward Island																				
Enteritidis	14 (50.0)	6	8															1	8	
Typhimurium	4 (14.3)	3			1			1	1					1			1			1
4,[5],12:i:-	3 (10.7)				3			3	3					3						3
Other serovars	3 (10.7)	2	1						1	1	1	1								
Heidelberg	2 (7.1)	2																		
Newport	2 (7.1)	2																		
Total	**28 (100)**	**15**	**9**		**4**			**4**	**5**	**1**	**1**	**1**		**4**			**1**	**1**	**8**	**4**
Newfoundland and Labrador																				
Enteritidis	26 (57.8)	20	6																6	
Heidelberg	9 (20.0)	2	2	5			1	6	4	4	4	4		1					1	
Other serovars	6 (13.3)	6																		
Newport	2 (4.4)	1			1			1	1	1	1	1		1			1			1
Typhimurium	2 (4.4)	2																		
Total	**45 (100)**	**31**	**8**	**5**	**1**		**1**	**7**	**5**	**5**	**5**	**5**		**2**			**1**		**7**	**1**
National																				
Enteritidis	1,165 (45.4)	806	311	32	16		3	15	39	1	3	1		27	20		3	20	317	42
Typhimurium	323 (12.6)	203	19	29	59	13	3	87	80	7	11	3		98	18	5	56	6	16	93
Heidelberg	315 (12.3)	184	85	38	8		26	85	61	47	49	46		29	6	1	6		5	14
Other serovars	262 (10.2)	207	10	7	25	13	10	37	36	15	21	15		38	14	1	26	12	36	45
Newport	185 (7.2)	166	2	3	13	1	3	14	12	7	6	6		16	7	2	11		4	17
4,[5],12:i:-	155 (6.0)	50	13	19	68	5	15	87	85	3	6	3		88	8	3	11	3	7	91
Typhi	137 (5.3)	19	82	7	28	1		37	27			1		30	30		29	18	114	4
Paratyphi A and B	25 (1.0)	3	22															5	22	
Total	**2,567 (100)**	**1,638**	**544**	**135**	**217**	**33**	**60**	**362**	**340**	**80**	**96**	**75**		**326**	**103**	**12**	**142**	**64**	**521**	**306**

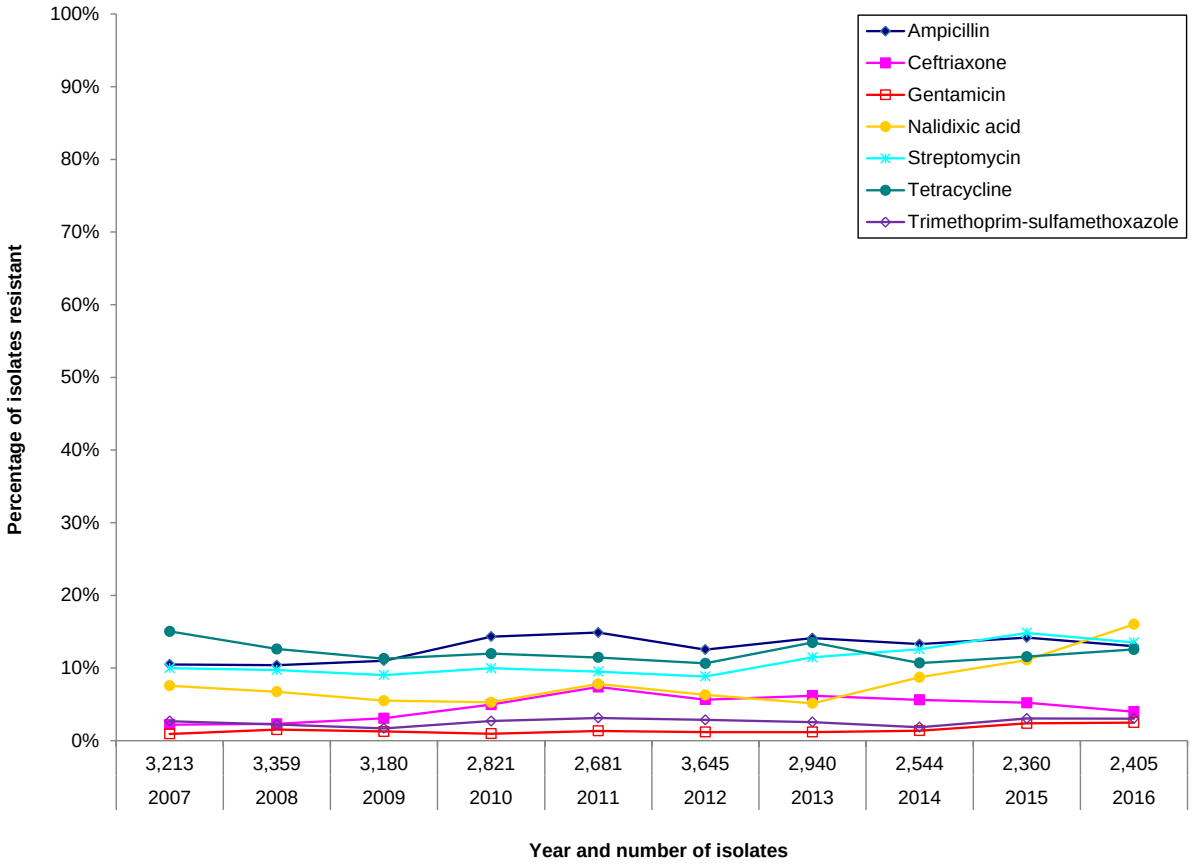
Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

Salmonella Paratyphi B does not include *S*. Paratyphi B var. L (+) tartrate (+), formerly called *S*. Paratyphi var. Java. The biotype of *S*. Paratyphi B included here is tartrate (-) and associated with severe typhoid-like fever. *Salmonella* Paratyphi B var. L (+) tartrate (+) is commonly associated with gastrointestinal illness.

Temporal antimicrobial resistance summary

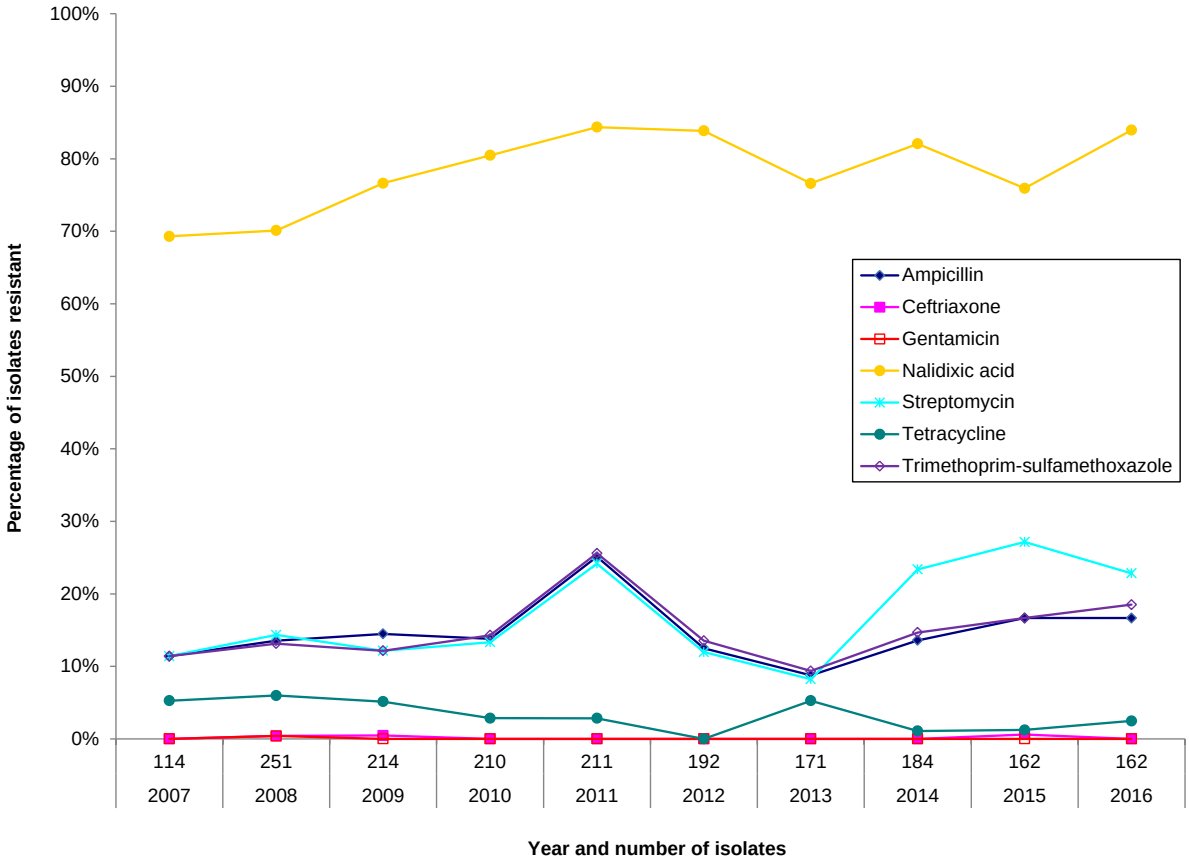
Figure 4. 2 Temporal variations in resistance of non-typhoidal *Salmonella* from humans, 2007 to 2016



Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Number of isolates	3,213	3,359	3,180	2,821	2,681	3,645	2,940	2,544	2,360	2,405
Antimicrobial										
Ampicillin	**10%**	10%	11%	14%	15%	13%	14%	13%	**14%**	**13%**
Ceftriaxone	**2%**	2%	3%	5%	7%	6%	6%	6%	**5%**	**4%**
Gentamicin	**1%**	2%	1%	1%	1%	1%	1%	1%	**2%**	**2%**
Nalidixic acid	**8%**	7%	6%	5%	8%	6%	5%	9%	**11%**	**16%**
Streptomycin	**10%**	10%	9%	10%	10%	9%	11%	13%	**15%**	**14%**
Tetracycline	**15%**	13%	11%	12%	11%	11%	14%	11%	**12%**	**13%**
Trimethoprim-sulfamethoxazole	**3%**	2%	2%	3%	3%	3%	3%	2%	**3%**	**3%**

For the temporal analyses, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the previous 10 years and the preceding surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given antimicrobial.

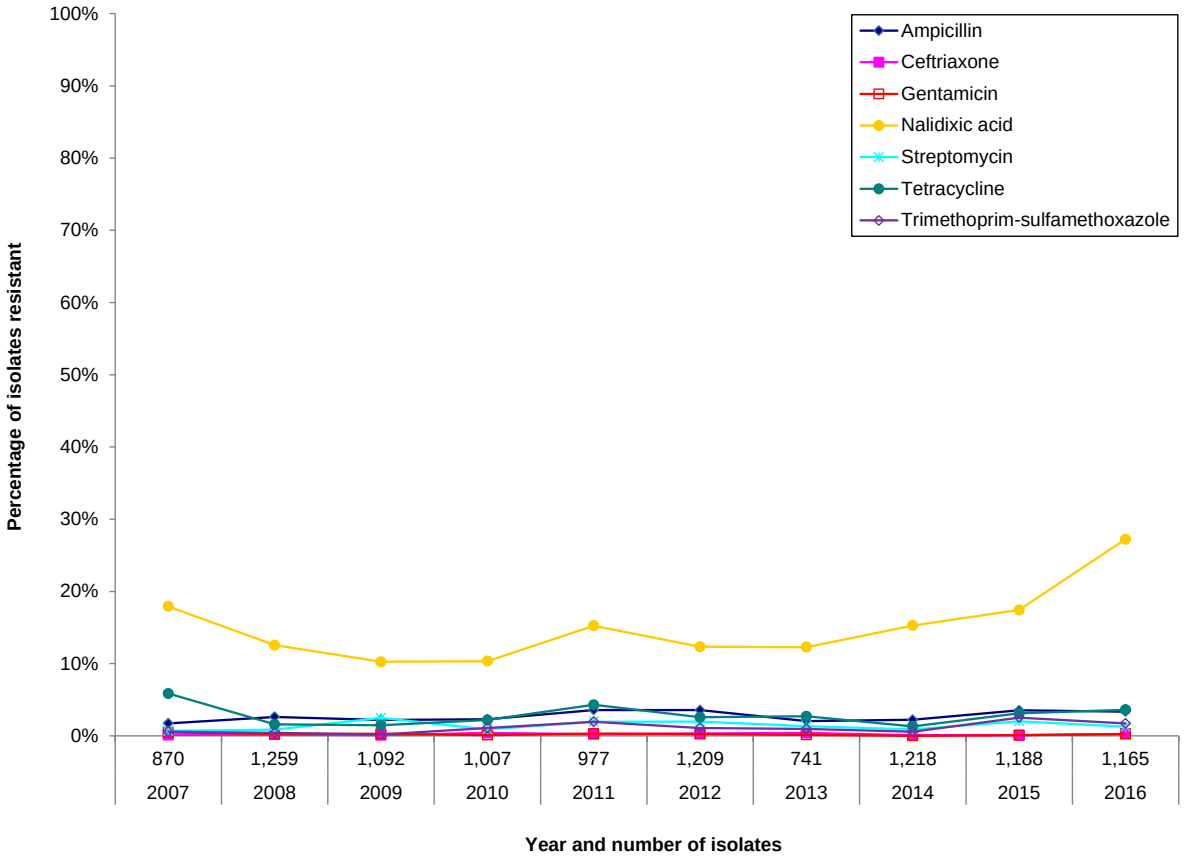
Figure 4. 3 Temporal variations in resistance of typhoidal *Salmonella* from humans, 2007 to 2016



Year Number of isolates	2007 114	2008 251	2009 214	2010 210	2011 211	2012 192	2013 171	2014 184	2015 162	2016 162
Antimicrobial										
Ampicillin	**11%**	14%	14%	14%	25%	13%	9%	14%	**17%**	**17%**
Ceftriaxone	**0%**	0%	0%	0%	0%	0%	0%	0%	**1%**	**0%**
Gentamicin	**0%**	0%	0%	0%	0%	0%	0%	0%	**0%**	**0%**
Nalidixic acid	**69%**	70%	77%	80%	84%	84%	77%	82%	**76%**	**84%**
Streptomycin	**11%**	14%	12%	13%	24%	12%	8%	23%	**27%**	**23%**
Tetracycline	**5%**	6%	5%	3%	3%	0%	5%	1%	**1%**	**2%**
Trimethoprim-sulfamethoxazole	**11%**	13%	12%	14%	26%	14%	9%	15%	**17%**	**19%**

For the temporal analyses, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the previous 10 years and the preceding surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given antimicrobial.

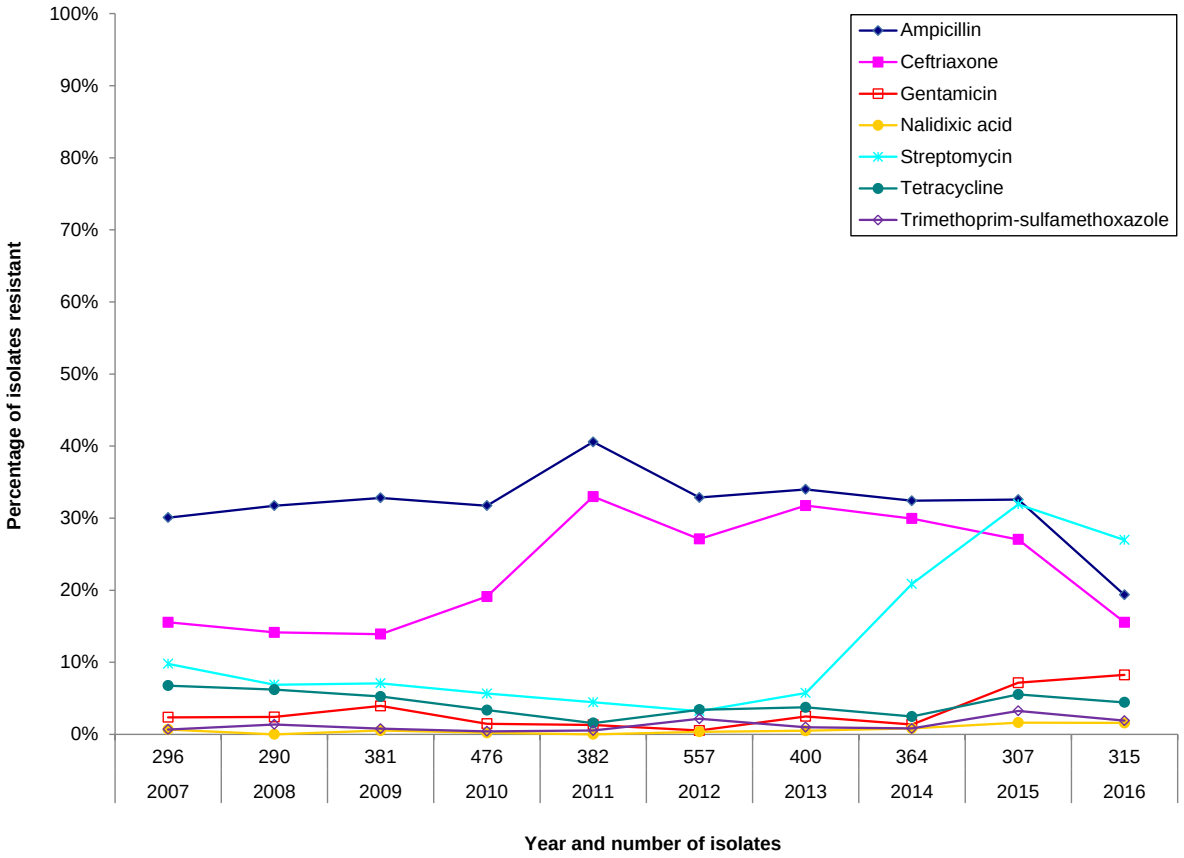
Figure 4. 4 Temporal variations in resistance of *Salmonella* Enteritidis from humans, 2007 to 2016



Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Number of isolates	870	1,259	1,092	1,007	977	1,209	741	1,218	1,188	1,165
Antimicrobial										
Ampicillin	**2%**	3%	2%	2%	4%	4%	2%	2%	**4%**	**3%**
Ceftriaxone	**0%**	0%	0%	0%	0%	0%	0%	0%	**0%**	**0%**
Gentamicin	**0%**	0%	0%	0%	0%	0%	0%	0%	**0%**	**0%**
Nalidixic acid	**18%**	13%	10%	10%	15%	12%	12%	15%	**17%**	**27%**
Streptomycin	**1%**	1%	2%	1%	2%	2%	1%	1%	**2%**	**1%**
Tetracycline	**6%**	2%	1%	2%	4%	3%	3%	1%	**3%**	**4%**
Trimethoprim-sulfamethoxazole	**1%**	0%	0%	1%	2%	1%	1%	1%	**3%**	**2%**

For the temporal analyses, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the previous 10 years and the preceding surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given antimicrobial.

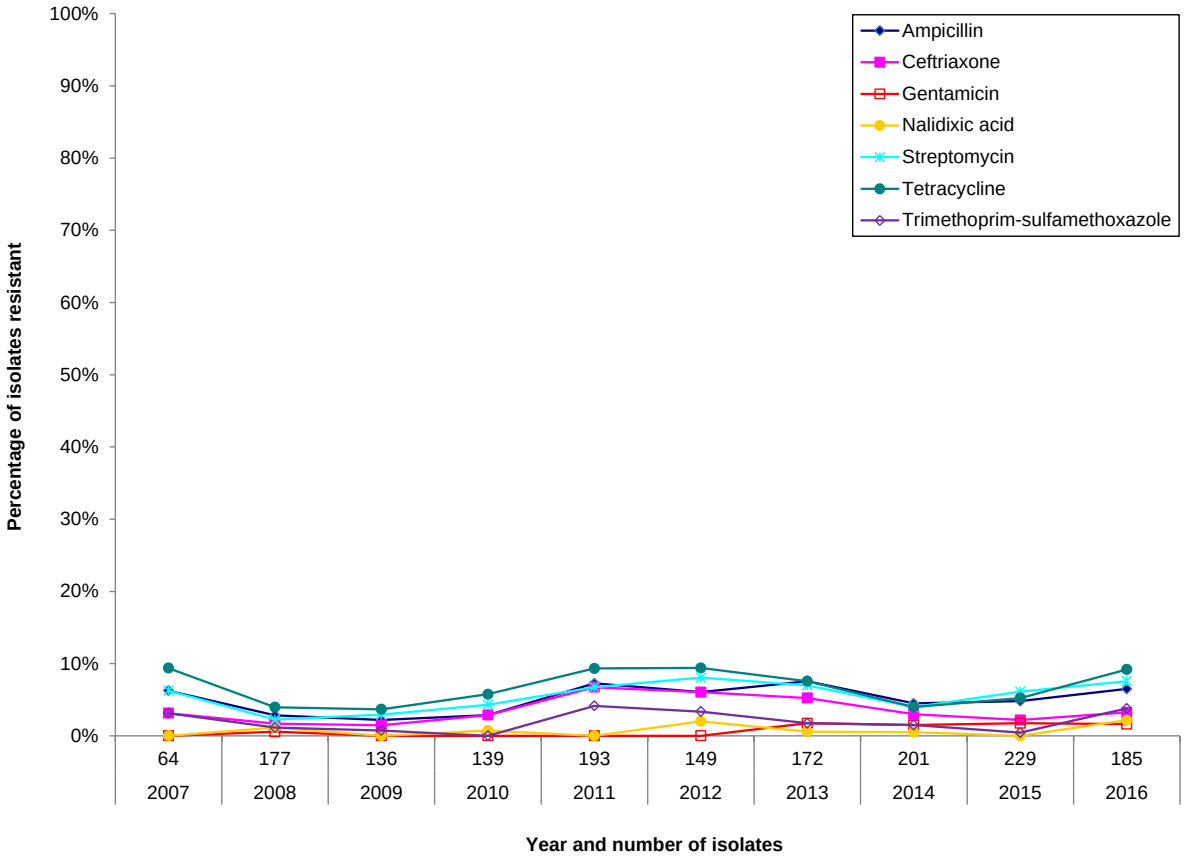
Figure 4. 5 Temporal variations in resistance of *Salmonella* Heidelberg from humans, 2007 to 2016



Year Number of isolates	2007 296	2008 290	2009 381	2010 476	2011 382	2012 557	2013 400	2014 364	2015 307	2016 315
Antimicrobial										
Ampicillin	**30%**	32%	33%	32%	41%	33%	34%	32%	**33%**	**19%**
Ceftriaxone	**16%**	14%	14%	19%	33%	27%	32%	30%	**27%**	**16%**
Gentamicin	**2%**	2%	4%	1%	1%	1%	3%	1%	**7%**	**8%**
Nalidixic acid	**1%**	0%	1%	0%	0%	0%	1%	1%	**2%**	**2%**
Streptomycin	**10%**	7%	7%	6%	4%	3%	6%	21%	**32%**	**27%**
Tetracycline	**7%**	6%	5%	3%	2%	3%	4%	2%	**6%**	**4%**
Trimethoprim-sulfamethoxazole	**1%**	1%	1%	0%	1%	2%	1%	1%	**3%**	**2%**

For the temporal analyses, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the previous 10 years and the preceding surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given antimicrobial.

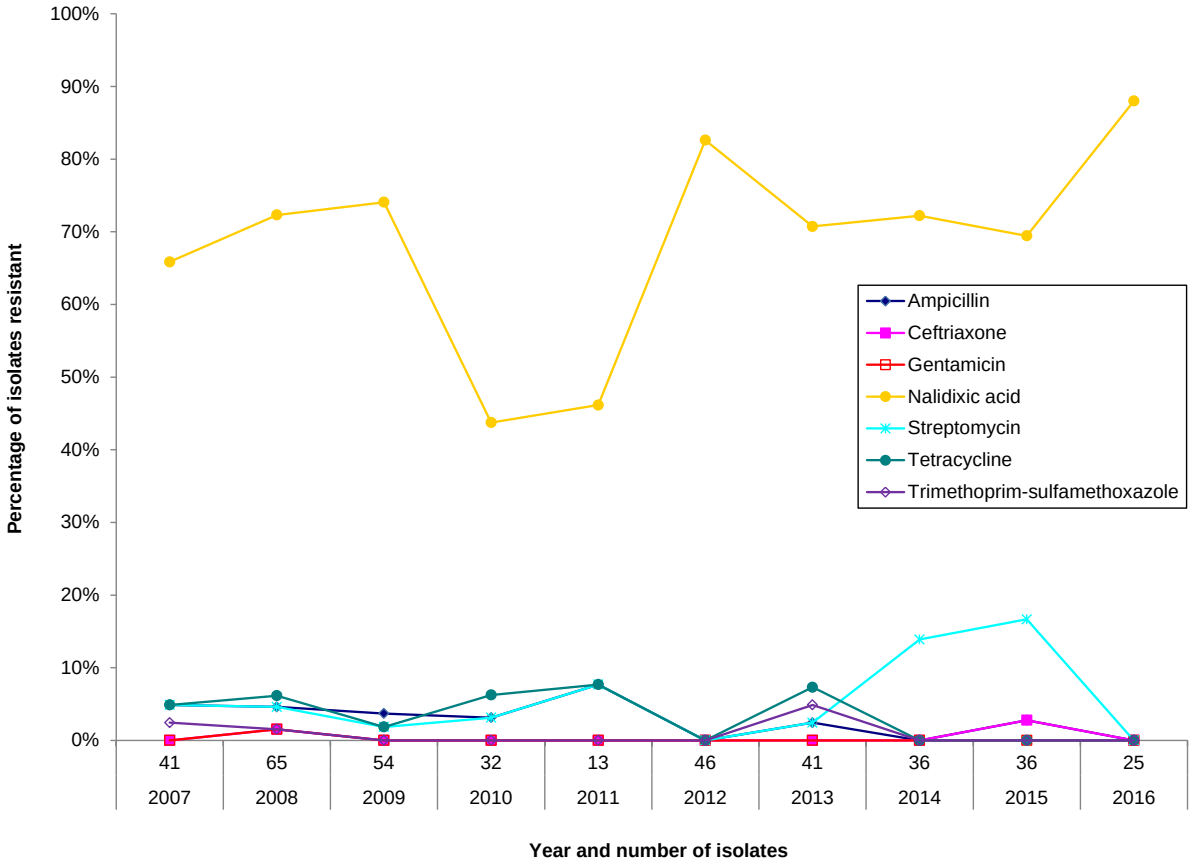
Figure 4. 6 Temporal variations in resistance of *Salmonella* Newport from humans, 2007 to 2016



Year Number of isolates	2007 64	2008 177	2009 136	2010 139	2011 193	2012 149	2013 172	2014 201	2015 229	2016 185
Antimicrobial										
Ampicillin	**6%**	3%	2%	3%	7%	6%	8%	4%	**5%**	**6%**
Ceftriaxone	**3%**	2%	1%	3%	7%	6%	5%	3%	**2%**	**3%**
Gentamicin	**0%**	1%	0%	0%	0%	0%	2%	1%	**2%**	**2%**
Nalidixic acid	**0%**	1%	0%	1%	0%	2%	1%	0%	**0%**	**2%**
Streptomycin	**6%**	2%	3%	4%	7%	8%	7%	4%	**6%**	**8%**
Tetracycline	**9%**	4%	4%	6%	9%	9%	8%	4%	**5%**	**9%**
Trimethoprim-sulfamethoxazole	**3%**	1%	1%	0%	4%	3%	2%	1%	**0%**	**4%**

For the temporal analyses, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the previous 10 years and the preceding surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given antimicrobial.

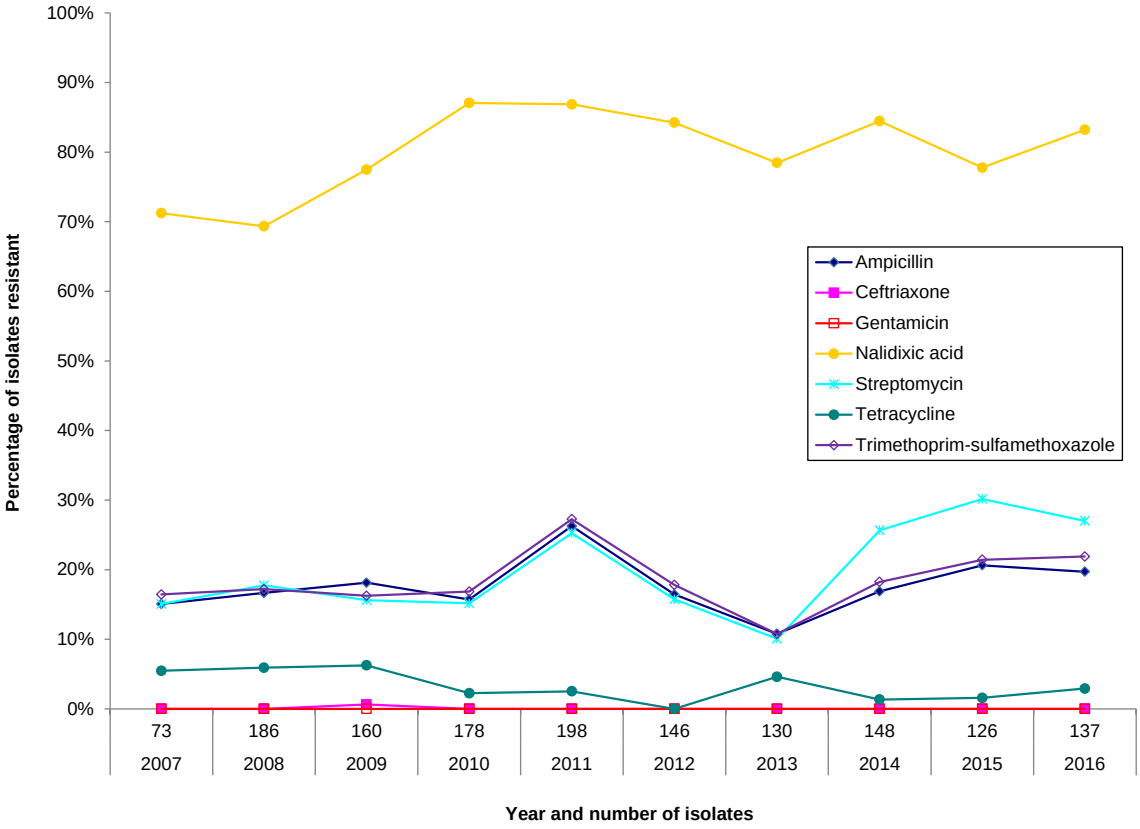
Figure 4. 7 Temporal variations in resistance of *Salmonella* Paratyphi A and B from humans, 2007 to 2016



Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Number of isolates	41	65	54	32	13	46	41	36	36	25
Antimicrobial										
Ampicillin	**5%**	5%	4%	3%	8%	0%	2%	0%	**3%**	**0%**
Ceftriaxone	**0%**	2%	0%	0%	0%	0%	0%	0%	**3%**	**0%**
Gentamicin	**0%**	2%	0%	0%	0%	0%	0%	0%	**0%**	**0%**
Nalidixic acid	**66%**	72%	74%	44%	46%	83%	71%	72%	**69%**	**88%**
Streptomycin	**5%**	5%	2%	3%	8%	0%	2%	14%	**17%**	**0%**
Tetracycline	**5%**	6%	2%	6%	8%	0%	7%	0%	**0%**	**0%**
Trimethoprim-sulfamethoxazole	**2%**	2%	0%	0%	0%	0%	5%	0%	**0%**	**0%**

For the temporal analyses, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the previous 10 years and the preceding surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given antimicrobial.

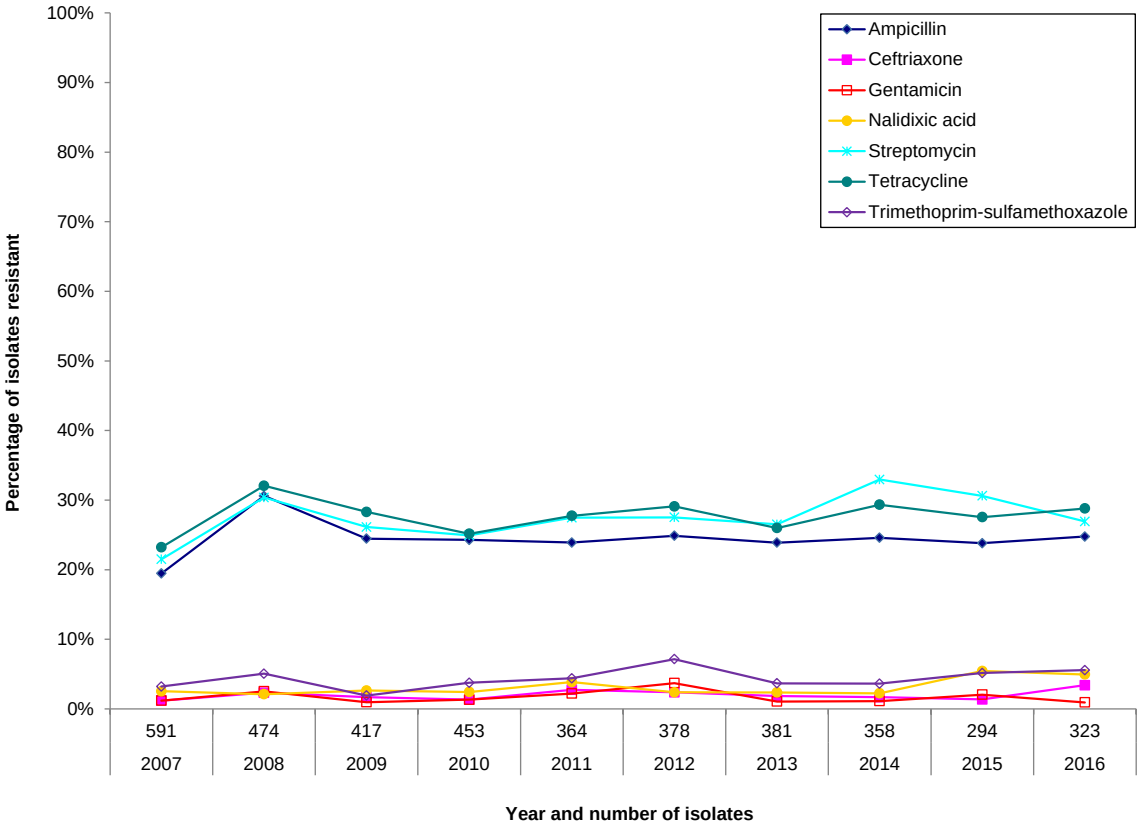
Figure 4. 8 Temporal variations in resistance of *Salmonella* Typhi from humans, 2007 to 2016



Year Number of isolates	2007 73	2008 186	2009 160	2010 178	2011 198	2012 146	2013 130	2014 148	2015 126	2016 137
Antimicrobial										
Ampicillin	**15%**	17%	18%	16%	26%	16%	11%	17%	**21%**	**20%**
Ceftriaxone	**0%**	0%	1%	0%	0%	0%	0%	0%	**0%**	**0%**
Gentamicin	**0%**	0%	0%	0%	0%	0%	0%	0%	**0%**	**0%**
Nalidixic acid	**71%**	69%	78%	87%	87%	84%	78%	84%	**78%**	**83%**
Streptomycin	**15%**	18%	16%	15%	25%	16%	10%	26%	**30%**	**27%**
Tetracycline	**5%**	6%	6%	2%	3%	0%	5%	1%	**2%**	**3%**
Trimethoprim-sulfamethoxazole	**16%**	17%	16%	17%	27%	18%	11%	18%	**21%**	**22%**

For the temporal analyses, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the previous 10 years and the preceding surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given antimicrobial.

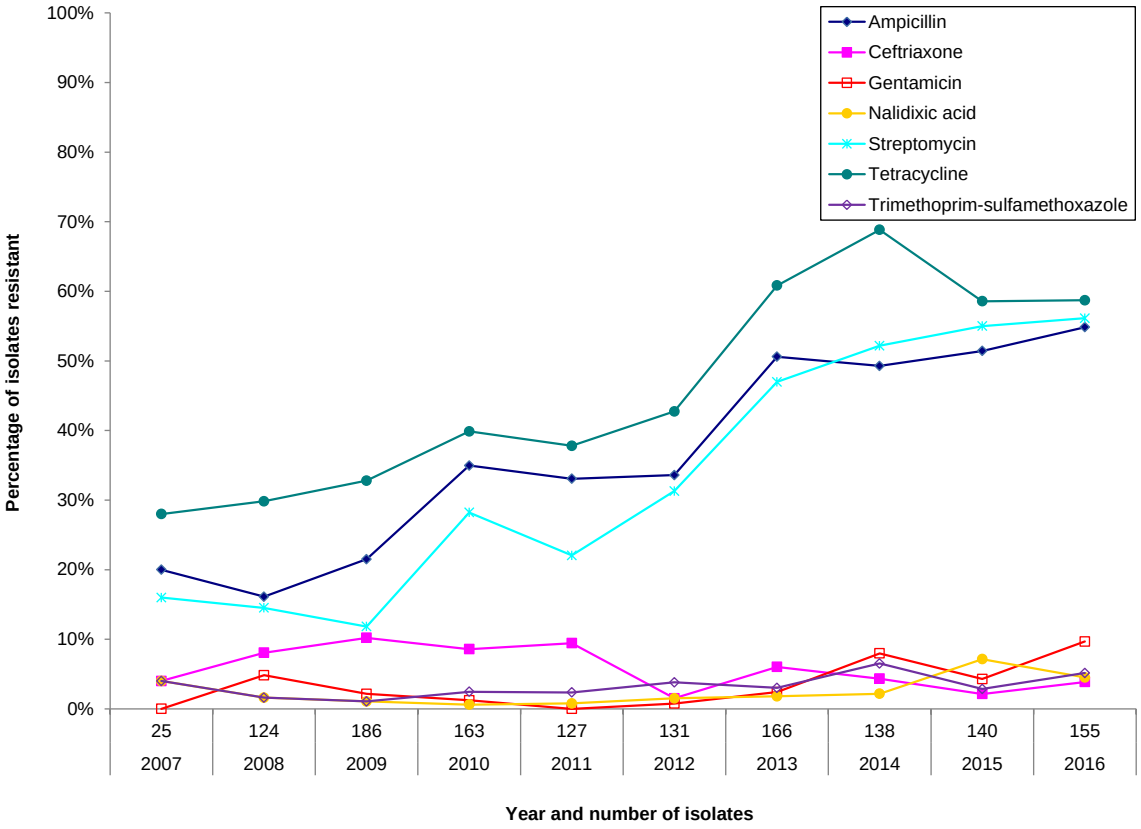
Figure 4. 9 Temporal variations in resistance of *Salmonella* Typhimurium from humans, 2007 to 2016



Year Number of isolates	2007 591	2008 474	2009 417	2010 453	2011 364	2012 378	2013 381	2014 358	2015 294	2016 323
Antimicrobial										
Ampicillin	**19%**	31%	24%	24%	24%	25%	24%	25%	**24%**	**25%**
Ceftriaxone	**1%**	2%	2%	1%	3%	2%	2%	2%	**1%**	**3%**
Gentamicin	**1%**	3%	1%	1%	2%	4%	1%	1%	**2%**	**1%**
Nalidixic acid	**3%**	2%	3%	2%	4%	2%	2%	2%	**5%**	**5%**
Streptomycin	**21%**	30%	26%	25%	27%	28%	27%	33%	**31%**	**27%**
Tetracycline	**23%**	32%	28%	25%	28%	29%	26%	29%	**28%**	**29%**
Trimethoprim-sulfamethoxazole	**3%**	5%	2%	4%	4%	7%	4%	4%	**5%**	**6%**

For the temporal analyses, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the previous 10 years and the preceding surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given antimicrobial.

Figure 4. 10 Temporal variations in resistance of *Salmonella* 4,[5],12:i:- from humans, 2007 to 2016



Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Number of isolates	25	124	186	163	127	131	166	138	140	155
Antimicrobial										
Ampicillin	**20%**	16%	22%	35%	33%	34%	51%	49%	**51%**	**55%**
Ceftriaxone	**4%**	8%	10%	9%	9%	2%	6%	4%	**2%**	**4%**
Gentamicin	**0%**	5%	2%	1%	0%	1%	2%	8%	**4%**	**10%**
Nalidixic acid	**4%**	2%	1%	1%	1%	2%	2%	2%	**7%**	**5%**
Streptomycin	**16%**	15%	12%	28%	22%	31%	47%	52%	**55%**	**56%**
Tetracycline	**28%**	30%	33%	40%	38%	43%	61%	69%	**59%**	**59%**
Trimethoprim-sulfamethoxazole	**4%**	2%	1%	2%	2%	4%	3%	7%	**3%**	**5%**

For the temporal analyses, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the previous 10 years and the preceding surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given antimicrobial.

Retail Meat Surveillance[65]

Key findings

A summary of Retail Meat Surveillance recovery rates are presented in Table 4. 10.

Beef

Escherichia coli (n = 256)

As in previous years, overall resistance levels of Category I β-lactams (amoxicillin-clavulanic acid and ceftriaxone) remained low (1/256 and 2/256 respectively) in beef *E. coli* isolates in 2016. The only provinces where Category I β-lactam resistance was observed in 2016 were British Columbia (3%, 2/58) and Ontario (1%, 1/68) (Table 4. 2). Similar to 2015, no *E. coli* from beef were resistant to all 7 classes of antimicrobials tested (Table 4. 2). No ciprofloxacin or meropenem resistance was observed among *E. coli* isolated from beef.

In multiple provinces/regions, resistance to tetracycline was significantly lower in 2016 compared to previous years. For example, resistance to tetracycline was significantly lower in British Columbia in 2016 (12%, 7/59) compared to in 2012 (36%, 27/76) as well as significantly lower in Ontario in 2016 (15%, 10/68) compared to both 2015 and 2012 (34%, 18/53; 30%, 33/110, respectively). Tetracycline resistance was also significantly lower in Québec in 2016 (12%, 10/82) compared to 2015 (27%, 21/79) (Figure 4. 11).

Chicken

Salmonella (n = 183)

Across all provinces sampled, the top 3 chicken *Salmonella* serovars in 2016 were Enteritidis, Kentucky, and Heidelberg, as in 2015. Regional differences in serovar distribution were observed in 2016 with Enteritidis being the most common serovar in the western Canadian provinces/regions of British Columbia (61%, 38/62) and the Prairies (79%, 22/28). In Ontario the most common serovar was Infantis (23%, 5/22 and in Québec the most common serovar was Kentucky (62%, 44/71) by a substantial amount. Additionally, unlike recent years, no Heidelberg was isolated at all from either British Columbia or the Prairies (Table 4. 3). Unlike 2015 where a single isolate of Enteritidis from retail chicken was found to be resistant to ampicillin only; no Enteritidis isolates were resistant in 2016. In 2016, no ciprofloxacin or meropenem resistance was observed (Table 4. 3).

In 2016, across all provinces sampled, resistance levels of Category I β-lactams (amoxicillin-clavulanic acid and ceftriaxone) (7%, 12/183) were lower compared to levels in 2015 (13%, 36/281) (Figure 4. 12). Resistance to ceftriaxone was significantly lower (5%, 3/62) in 2016 than 2012 (40%, 21/53) in British Columbia (Figure 4. 12). Resistance to ceftriaxone was

[65] For 2016, due to limited sampling technician availability, only a partial year's worth of retail sampling was conducted in Ontario and the Prairies. Sampling target and isolate yields were therefore not achieved. All 2016 Ontario and Prairie retail data should be interpreted with caution. Additionally in 2016, retail sampling activities in the Atlantic region were suspended due to budgetary constraints.

significantly lower (5%, 1/22) in 2016 than 2004 (46%, 25/54) in Ontario (data not shown)[66]. Resistance to ceftriaxone was significantly lower (8%, 6/71) in 2016 than 2012 (28%, 30/106) (Figure 4. 12) and 2004 (40%, 21/53) (data not shown) in Québec.

Escherichia coli (n = 310)

In general, resistance levels of Category I β-lactams (amoxicillin-clavulanic acid and ceftriaxone) in 2016 were lower (9%, 29/311) compared to those in 2015 (17%, 61/365) across all provinces/regions sampled (data not shown).

Resistance to ceftriaxone was significantly lower in 2016 (17%, 14/81) than 2012 (41%, 34/82) in British Columbia (Figure 4. 13). Resistance to ceftriaxone was significantly lower in 2016 (4%, 3/75) than 2012 (19%, 20/107) (Figure 4. 13), 2006 (28%, 42/152) and 2004 (24%, 36/150) (data not shown) in Ontario[67]. Resistance to ceftriaxone was significantly lower in 2016 (8%, 9/118) than 2012 (26%, 34/133) and 2004 (40%, 63/158) in Québec (Figure 4. 13).

Resistance to gentamicin was significantly higher in 2016 (33%, 27/81) than 2015 (11%, 7/62) and 2012 (12%, 10/82) in British Columbia (Figure 4. 13). Resistance to gentamicin was significantly higher in 2016 (28%, 10/36) than 2012 (9%, 6/67) in the Prairies (Figure 4. 13). Resistance to gentamicin was significantly higher in 2016 (41%, 48/118) than 2015 and 2012 (28%, 35/127; 24%, 32/133 respectively) in Québec.

Ciprofloxacin resistance was observed among 3/81 (4%) *E. coli* isolates from chicken in British Columbia only. This is the highest level of ciprofloxacin resistance among *E. coli* from chicken to-date and is the first time ciprofloxacin resistance has been observed in British Columbia in this bacteria-commodity pairing at retail. In the past, only a single isolate resistant to this drug was observed in 2008 (Québec), 2009 (Atlantic region) and 2013 (Québec). No isolates were resistant to meropenem or resistant to 6 or 7 antimicrobial classes (Table 4. 4).

Campylobacter (n = 176)

Ciprofloxacin resistance remained highest in British Columbia in 2016 (35%, 23/65) across provinces/regions sampled followed by Ontario (15%, 7/46) and the Prairies and Québec at 6% each (1/16 and 3/49, respectively). Ciprofloxacin resistance was significantly higher in 2016 (35%, 23/65) than 2012 (8%, 6/73) in British Columbia (Figure 4. 14). No other increases or decreases in ciprofloxacin resistance were significant in 2016. Unlike previous years where low levels of telithromycin resistance were observed across most or all provinces/regions sampled, in 2016 no telithromycin resistance was observed (Table 4. 5 and Figure 4. 14).

[66] Additional temporal analyses for ampicillin and ceftiofur/ceftriaxone were conducted for *Salmonella* isolates from Ontario and Québec. These 2 antimicrobials, provinces, and years (2004 and 2006) were selected due to a change in ceftiofur use practices by Québec chicken hatcheries in early 2005 and in 2007 (start and end of the voluntary period of withdrawal). Data for 2004 and 2006 are not shown in figures and tables.

[67] Additional temporal analyses for ampicillin and ceftiofur/ceftriaxone were conducted for *Salmonella* isolates from Ontario and Québec. These 2 antimicrobials, provinces, and years (2004 and 2006) were selected due to a change in ceftiofur use practices by Québec chicken hatcheries in early 2005 and in 2007 (start and end of the voluntary period of withdrawal). Data for 2004 and 2006 are not shown in figures and tables.

Pork

Escherichia coli (n = 140)

In 2016, Category I β-lactam ceftriaxone resistance levels in pork *E. coli* isolates remained stable at low (3%, 4/140), similar levels compared to recent previous years at the national level (Figure 4. 15). In the Prairies, 17% of pork *E. coli* isolates were resistant to ceftriaxone but this was only based on a total of 6 isolates (i.e. 1/6) so should be interpreted with extreme caution. Two isolates from Ontario (4%, 2/51) were resistant to azithromycin and were also resistant to 6 antimicrobial classes with the following pattern (ACSSuT-AZM-SXT) (Table 4. 6). In 2016 no ciprofloxacin or meropenem resistance was observed.

Turkey

Salmonella (n = 97)

As in previous years, the distribution of *Salmonella* serovars varied greatly by province/region for retail surveillance of ground turkey (Table 4. 7). No meropenem as well as ciprofloxacin or nalidixic acid resistance was observed (Table 4. 7). No isolates were resistant to 7 antimicrobial classes. Category I β-lactam (amoxicillin-clavulanic acid and ceftriaxone) resistance in turkey *Salmonella* isolates was only observed British Columbia (3%, 1/37 for both antimicrobials) and Québec (15%, 5/33 and 12%, 4/33, respectively) (Table 4. 7). Resistance to ceftriaxone was significantly lower in 2016 (3%, 1/37) than 2012 (37%, 10/27) in British Columbia (Figure 4. 16). Resistance to gentamicin was significantly higher in 2016 in Ontario and Québec (40%, 6/15; 24%, 8/33 respectively) than 2012 (7%, 3/44; 2%, 1/51 respectively) (Figure 4. 16).

Escherichia coli (n = 283)

Unlike 2015 where ciprofloxacin resistance was observed in most provinces/regions at low-levels (less than or equal to 3%) with the exception of British Columbia (no ciprofloxacin resistance in 2015), in 2016, ciprofloxacin resistance in turkey *E. coli* isolates was only observed in Québec (1%, 1/107) (Table 4. 8). In 2016, resistance levels of Category I β-lactams (amoxicillin-clavulanic acid and ceftriaxone) in turkey *E. coli* isolates ranged from 0% in Ontario (0/64) to 6 to 7% in British Columbia (5/80), the Prairies (2/32) and Québec (8/107) (Table 4. 8). Resistance to ceftriaxone was significantly lower in Ontario in 2016 (0%, 0/64) than 2012 (9%, 13/151) (Figure 4. 17). Resistance to gentamicin was significantly higher in 2016 in British Columbia (26%, 21/80), the Prairies (31%, 10/32) and Québec (21%, 22/107) than 2012 (7%, 7/101; 14%, 11/81; 9%, 16/170 respectively) (Figure 4. 17). One isolate from Québec was resistant to 6 antimicrobial classes with the following pattern ACSSuT-AMC-FOX-CRO-GEN-NAL. No isolates were resistant to meropenem.

Campylobacter (n = 25)

In 2016, ciprofloxacin resistance among *Campylobacter* from turkey was only observed in western Canada as follows: 10% (1/10) of isolates from British Columbia and 33% (1/3) isolates from the Prairies (Table 4. 9). Resistance to telithromycin was observed in 2/6 (33%) isolates from Québec and the only instances of resistance to lincosamides and macrolides were also observed in these 2 isolates with the following patterns: AZM-CLI-ERY-TEL and ERY-

TEL (Table 4. 9). Due to the low yield of *Campylobacter* spp. from ground turkey at retail, CIPARS will not attempt to culture this organism from this commodity in 2017.

Multiclass resistance

Table 4. 2 Number of antimicrobial classes in resistance patterns of *Escherichia coli* from beef, 2016

Province or region	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial											
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
British Columbia	58 (22.7)	50	2	1	5		1	6	4	1	1	1		6	2		3		1	7
Prairies	48 (18.8)	42	5	1				2						1						5
Ontario	68 (26.6)	57	3	5	3			6	6		1			6	1		3		1	10
Québec	82 (32.0)	70	8	3	1			5	1					4	1		1			10
National	**256 (100)**	**219**	**18**	**10**	**9**		**1**	**19**	**11**	**1**	**2**	**1**		**17**	**4**		**7**		**2**	**32**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

For Ontario and the Prairies in 2016, a partial year of retail sampling was conducted due to difficulties in staffing field personnel. As a result, the sampling target and subsequent isolate yields were not achieved and results should be interpreted with caution.

Table 4. 3 Number of antimicrobial classes in resistance patterns of *Salmonella* from chicken, 2016

Province or region/serovar	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial											
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
British Columbia																				
Enteritidis	38 (61.3)	38																		
Kentucky	10 (16.1)			10				10	2	2	2									10
Infantis	5 (8.1)	5																		
Schwarzengrund	5 (8.1)	5																		
Less common serovars	4 (6.5)	1	1	2			1	2	1	1	1	1		1	1					1
Total	**62 (100)**	**49**	**1**	**12**			**1**	**12**	**3**	**3**	**3**	**1**		**1**	**1**					**11**
Prairies																				
Enteritidis	22 (78.6)	22																		
Kentucky	3 (10.7)		1	2				2	2	2	2	2								2
Infantis	2 (7.1)	2																		
Senftenberg	1 (3.6)	1																		
Total	**28 (100)**	**25**	**1**	**2**				**2**	**2**	**2**	**2**	**2**								**2**
Ontario																				
Infantis	5 (22.7)	4			1		1	1	1	1	1	1		1			1			1
Heidelberg	4 (18.2)	4																		
Kentucky	4 (18.2)			4				4												4
Indiana	3 (13.6)	3																		
Enteritidis	2 (9.1)	2																		
Hadar	2 (9.1)	1		1				1												1
Rissen	1 (4.5)	1																		
Thompson	1 (4.5)	1																		
Total	**22 (100)**	**16**		**5**	**1**		**1**	**6**	**1**	**1**	**1**	**1**		**1**			**1**			**6**
Québec																				
Kentucky	44 (62)	2	1	41			1	41	4	4	4	4		2	1					41
Heidelberg	13 (18.3)	8	2	3			2	4	3	2	2	2		2						
Enteritidis	4 (5.6)	4																		
Infantis	3 (4.2)	3																		
Thompson	2 (2.8)	2																		
Less common serovars	5 (7)	2	1	2			1	1						2						2
Total	**71 (100)**	**21**	**4**	**46**			**4**	**46**	**7**	**6**	**6**	**6**		**6**	**1**					**43**
National																				
Enteritidis	66 (36.1)	66																		
Kentucky	61 (33.3)	2	2	57			1	57	8	8	8	6		2	1					57
Heidelberg	17 (9.3)	12	2	3			2	4	3	2	2	2		2						
Infantis	15 (8.2)	14			1		1	1	1	1	1	1		1			1			1
Schwarzengrund	5 (2.7)	5																		
Indiana	4 (2.2)	3		1			1	1						1						
Less common serovars	15 (8.2)	9	2	4			1	3	1	1	1	1		2	1					4
Total	**183 (100)**	**111**	**6**	**65**	**1**		**6**	**66**	**13**	**12**	**12**	**10**		**8**	**2**		**1**			**62**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

Serovars represented by less than 2% of isolates were classified as “Less common serovars”.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

For Ontario and the Prairies in 2016, a partial year of retail sampling was conducted due to difficulties in staffing field personnel. As a result, the sampling target and subsequent isolate yields were not achieved and results should be interpreted with caution.

Table 4. 4 Number of antimicrobial classes in resistance patterns of *Escherichia coli* from chicken, 2016

Province or region	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial											
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
British Columbia	81 (26.1)	12	8	36	25		27	50	47	15	14	14		38	13		1	3	10	48
Prairies	36 (11.6)	12	6	15	3		10	15	14	3	3	3		10	1		1		4	13
Ontario	75 (24.2)	33	10	27	5		17	22	14	3	3	3		22	7		1			28
Québec	118 (38.1)	18	13	61	26		48	78	48	10	9	10		73	32		10		1	73
National	**310 (100)**	**75**	**37**	**139**	**59**		**102**	**165**	**123**	**31**	**29**	**30**		**143**	**53**		**13**	**3**	**15**	**162**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

For Ontario and the Prairies in 2016, a partial year of retail sampling was conducted due to difficulties in staffing field personnel. As a result, the sampling target and subsequent isolate yields were not achieved and results should be interpreted with caution.

Table 4. 5 Number of antimicrobial classes in resistance patterns of *Campylobacter* from chicken, 2016

Province or region/species	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial								
							Aminoglycosides	Ketolides	Lincosamides	Macrolides		Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	TEL	CLI	AZM	ERY	FLR	CIP	NAL	TET
British Columbia															
Campylobacter jejuni	55 (84.6)	29	8	18									18	18	26
Campylobacter coli	10 (15.4)	5	2	3									5	5	3
Total	**65 (100)**	**34**	**10**	**21**									**23**	**23**	**29**
Prairies															
Campylobacter jejuni	15 (93.8)	7	8										1	1	7
Campylobacter coli	1 (6.3)	1													
Total	**16 (100)**	**8**	**8**										**1**	**1**	**7**
Ontario															
Campylobacter jejuni	42 (91.3)	22	14	6					1	1	1		5	5	19
Campylobacter coli	4 (8.7)	2	1	1						1	1		2	2	1
Total	**46 (100)**	**24**	**15**	**7**					**1**	**2**	**2**		**7**	**7**	**20**
Québec															
Campylobacter jejuni	47 (95.9)	24	21	2									3	3	22
Campylobacter coli	2 (4.1)		1	1						1	1				2
Total	**49 (100)**	**24**	**22**	**3**						**1**	**1**		**3**	**3**	**24**
National															
Campylobacter jejuni	159 (90.3)	82	51	26					1	1	1		27	27	74
Campylobacter coli	17 (9.7)	8	4	5						2	2		7	7	6
Total	**176 (100)**	**90**	**55**	**31**					**1**	**3**	**3**		**34**	**34**	**80**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

For Ontario and the Prairies in 2016, a partial year of retail sampling was conducted due to difficulties in staffing field personnel. As a result, the sampling target and subsequent isolate yields were not achieved and results should be interpreted with caution.

Table 4. 6 Number of antimicrobial classes in resistance patterns of *Escherichia coli* from pork, 2016

Province or region	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial											
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
British Columbia	40 (28.6)	30	6	3	1			3	3	2	1	2		4			1			6
Prairies	6 (4.3)	4			2			2	2	1	1	1		2						2
Ontario	51 (36.4)	21	9	9	10	2	2	18	16	1	1			16	8	2	7			27
Québec	43 (30.7)	23	5	11	4			11	8	2	1	2		9	6		3			18
National	**140 (100)**	**78**	**20**	**23**	**17**	**2**	**2**	**34**	**29**	**6**	**4**	**5**		**31**	**14**	**2**	**11**			**53**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

For Ontario and the Prairies in 2016, a partial year of retail sampling was conducted due to difficulties in staffing field personnel. As a result, the sampling target and subsequent isolate yields were not achieved and results should be interpreted with caution.

Table 4. 7 Number of antimicrobial classes in resistance patterns of *Salmonella* from turkey, 2016

Province or region/serovar	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial											
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
British Columbia																				
Enteritidis	13 (35.1)	13																		
Hadar	8 (21.6)			8				8	6											8
Reading	5 (13.5)	5																		
Infantis	3 (8.1)	2	1						1	1	1	1								
Berta	2 (5.4)	1	1					1												
Senftenberg	2 (5.4)	1		1			1		1											
Heidelberg	1 (2.7)	1																		
1,4,[5],12:1:-	1 (2.7)				1			1	1					1						1
Schwarzengrund	1 (2.7)	1																		
Worthington	1 (2.7)			1				1						1						1
Total	**37 (100)**	**24**	**2**	**10**	**1**		**1**	**11**	**9**	**1**	**1**	**1**		**2**						**10**
Prairies																				
Reading	6 (50.0)	4		2				2						2						2
Schwarzengrund	3 (25.0)	2		1				1						1						1
Hadar	2 (16.7)		1	1				1	2											1
Heidelberg	1 (8.3)			1			1	1						1						
Total	**12 (100)**	**6**	**1**	**5**			**1**	**5**	**2**					**4**						**4**
Ontario																				
Muenchen	5 (33.3)	3	1	1			1	1						1						1
Albany	4 (26.7)	2	2				2													
Heidelberg	2 (13.3)			2			2	2						2						
Bredeney	1 (6.7)		1				1													
Kentucky	1 (6.7)			1				1												1
Manhattan	1 (6.7)			1				1						1						1
Reading	1 (6.7)	1																		
Total	**15 (100)**	**6**	**4**	**5**			**6**	**5**						**4**						**3**
Québec																				
Heidelberg	14 (42.4)	5	2	7			5	7	4	4	4	2		5						
Muenchen	8 (24.2)	6	2				2													
Thompson	2 (6.1)	2																		
Typhimurium	2 (6.1)	1		1										1						1
Agona	1 (3.0)			1			1	1						1						
6,7:-:1,5	1 (3.0)	1																		
Kentucky	1 (3.0)			1				1												1
Montevideo	1 (3.0)			1				1	1	1										
Reading	1 (3.0)				1			1	1					1						1
Saintpaul	1 (3.0)	1																		
Schwarzengrund	1 (3.0)	1																		
Total	**33 (100)**	**17**	**4**	**11**	**1**		**8**	**11**	**6**	**5**	**4**	**2**		**8**						**3**
National																				
Heidelberg	18 (18.6)	6	2	10			8	10	4	4	4	2		8						
Enteritidis	13 (13.4)	13																		
Muenchen	13 (13.4)	9	3	1			3	1						1						1
Reading	13 (13.4)	10		2	1			3	1					3						3
Hadar	10 (10.3)		1	9				9	8											9
Schwarzengrund	5 (5.2)	4		1				1						1						1
Albany	4 (4.1)	2	2				2													
Infantis	3 (3.1)	2	1						1	1	1	1								
Berta	2 (2.1)	1	1					1												
Kentucky	2 (2.1)			2				2												2
Senftenberg	2 (2.1)	1		1			1		1											
Thompson	2 (2.1)	2																		
Typhimurium	2 (2.1)	1		1										1						1
Less common serovars	8 (8.2)	2	1	4	1		2	5	2	1				4						3
Total	**97 (100)**	**53**	**11**	**31**	**2**		**16**	**32**	**17**	**6**	**5**	**3**		**18**						**20**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

Serovars represented by less than 2% of isolates were classified as “Less common serovars”.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

For Ontario and the Prairies in 2016, a partial year of retail sampling was conducted due to difficulties in staffing field personnel. As a result, the sampling target and subsequent isolate yields were not achieved and results should be interpreted with caution.

Table 4. 8 Number of antimicrobial classes in resistance patterns of *Escherichia coli* from turkey, 2016

Province or region	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial												
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
British Columbia	80 (28.3)	17	16	34	13		21	45	27	5	5	4		25	5		7		4	49
Prairies	32 (11.3)	10	4	13	5		10	16	8	2	2	2		10			2			21
Ontario	64 (22.6)	23	9	25	7		8	24	15					19	8		1			39
Québec	107 (37.8)	45	8	32	21	1	22	45	35	8	8	7		32	5	1	5	1	3	56
National	**283 (100)**	**95**	**37**	**104**	**46**	**1**	**61**	**130**	**85**	**15**	**15**	**13**		**86**	**18**	**1**	**15**	**1**	**7**	**165**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

For Ontario and the Prairies in 2016, a partial year of retail sampling was conducted due to difficulties in staffing field personnel. As a result, the sampling target and subsequent isolate yields were not achieved and results should be interpreted with caution.

Table 4. 9 Number of antimicrobial classes in resistance patterns of *Campylobacter* from turkey, 2016

Province or region/species	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial							
							Aminoglycosides	Ketolides	Lincosamides	Macrolides		Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	TEL	CLI	AZM	ERY	FLR	CIP	NAL	TET
British Columbia															
Campylobacter jejuni	8 (80.0)	6	2												2
Campylobacter coli	2 (20.0)	1		1									1	1	1
Total	**10 (100)**	**7**	**2**	**1**									**1**	**1**	**3**
Prairies															
Campylobacter jejuni	2 (66.7)	1		1									1	1	1
Campylobacter coli	1 (33.3)	1													
Total	**3 (100)**	**2**		**1**									**1**	**1**	**1**
Ontario															
Campylobacter jejuni	4 (66.7)	1	3												3
Campylobacter coli	2 (33.3)	2													
Total	**6 (100)**	**3**	**3**												**3**
Québec															
Campylobacter coli	3 (50.0)	2		1				1	1	1	1				
Campylobacter jejuni	2 (33.3)	2													
Campylobacter spp.	1 (16.7)			1				1			1				
Total	**6 (100)**	**4**		**2**				**2**	**1**	**1**	**2**				
National															
Campylobacter jejuni	16 (64.0)	10	5	1									1	1	6
Campylobacter coli	8 (32.0)	6		2				1	1	1	1		1	1	1
Campylobacter spp.	1 (4.0)			1				1			1				
Total	**25 (100)**	**16**	**5**	**4**				**2**	**1**	**1**	**2**		**2**	**2**	**7**

Antimicrobial abbreviations are defined in the Appendix.

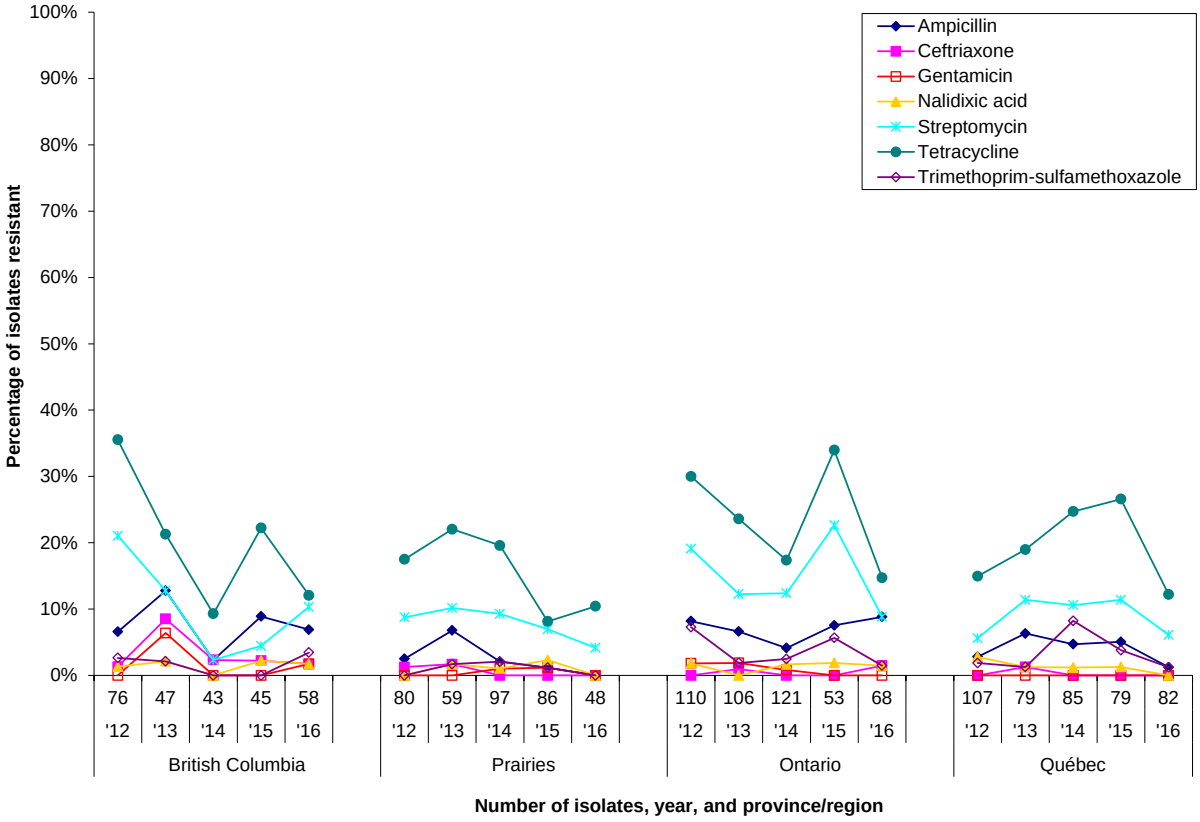
Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

For Ontario and the Prairies in 2016, a partial year of retail sampling was conducted due to difficulties in staffing field personnel. As a result, the sampling target and subsequent isolate yields were not achieved and results should be interpreted with caution.

Temporal antimicrobial resistance summary

Figure 4. 11 Temporal variations in resistance of *Escherichia coli* isolates from beef, 2012 to 2016



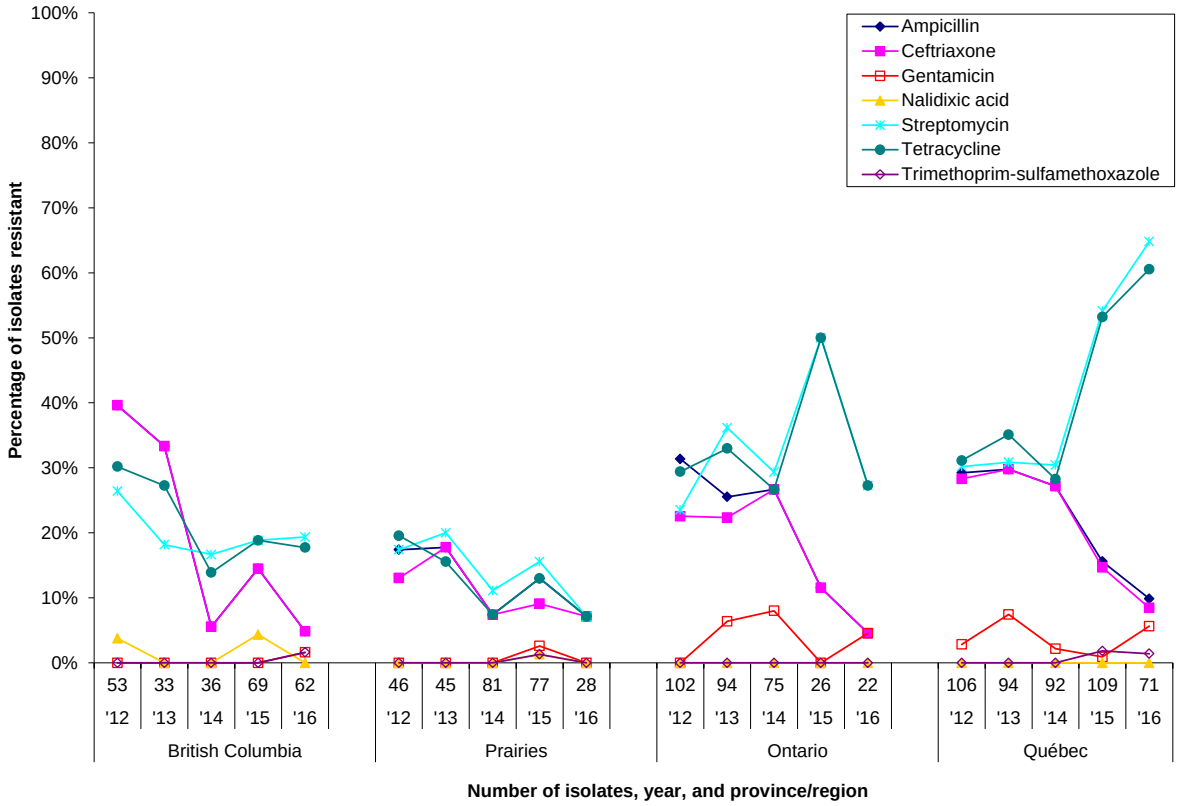
Province/region	British Columbia					Prairies					Ontario					Québec				
Year	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16
Number of isolates	76	47	43	45	58	80	59	97	86	48	110	106	121	53	68	107	79	85	79	82
Antimicrobial																				
Ampicillin	**7%**	13%	2%	**9%**	**7%**	**3%**	7%	2%	**1%**	**0%**	**8%**	7%	4%	**8%**	**9%**	**3%**	6%	5%	**5%**	**1%**
Ceftriaxone	**1%**	9%	2%	**2%**	**2%**	**1%**	2%	0%	**0%**	**0%**	**0%**	1%	0%	**0%**	**1%**	**0%**	1%	0%	**0%**	**0%**
Gentamicin	**0%**	6%	0%	**0%**	**2%**	**0%**	0%	1%	**1%**	**0%**	**2%**	2%	1%	**0%**	**0%**	**0%**	0%	0%	**0%**	**0%**
Nalidixic acid	**1%**	2%	0%	**2%**	**2%**	**0%**	2%	1%	**2%**	**0%**	**2%**	0%	2%	**2%**	**1%**	**3%**	1%	1%	**1%**	**0%**
Streptomycin	**21%**	13%	2%	**4%**	**10%**	**9%**	10%	9%	**7%**	**4%**	**19%**	12%	12%	**23%**	**9%**	**6%**	11%	11%	**11%**	**6%**
Tetracycline	**36%**	21%	9%	**22%**	**12%**	**18%**	22%	20%	**8%**	**10%**	**30%**	24%	17%	**34%**	**15%**	**15%**	19%	25%	**27%**	**12%**
Trimethoprim-sulfamethoxazole	**3%**	2%	0%	**0%**	**3%**	**0%**	2%	2%	**1%**	**0%**	**7%**	2%	2%	**6%**	**1%**	**2%**	1%	8%	**4%**	**1%**

For the temporal analyses by province/region, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the previous 5 years and the preceding surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given province/region and antimicrobial.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

For Ontario and the Prairies in 2016, a partial year of retail sampling was conducted due to difficulties in staffing field personnel. As a result, the sampling target and subsequent isolate yields in this province were not achieved and results should be interpreted with caution.

Figure 4. 12 Temporal variations in resistance of *Salmonella* isolates from chicken, 2012 to 2016



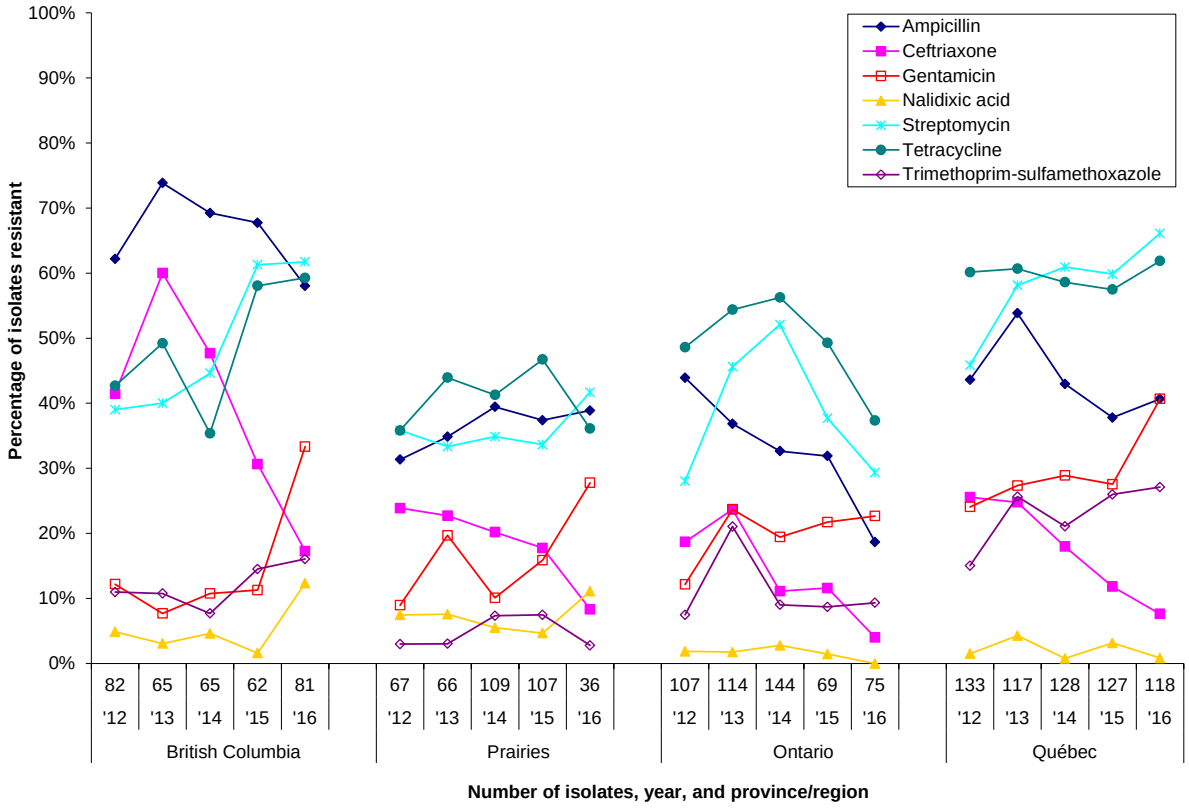
Province/region	British Columbia					Prairies					Ontario					Québec				
Year	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16
Number of isolates	53	33	36	69	62	46	45	81	77	28	102	94	75	26	22	106	94	92	109	71
Antimicrobial																				
Ampicillin	**40%**	33%	6%	**14%**	**5%**	**17%**	18%	7%	**13%**	**7%**	**31%**	26%	27%	**12%**	**5%**	**29%**	30%	27%	**16%**	**10%**
Ceftriaxone	**40%**	33%	6%	**14%**	**5%**	**13%**	18%	7%	**9%**	**7%**	**23%**	22%	27%	**12%**	**5%**	**28%**	30%	27%	**15%**	**8%**
Gentamicin	**0%**	0%	0%	**0%**	**2%**	**0%**	0%	0%	**3%**	**0%**	**0%**	6%	8%	**0%**	**5%**	**3%**	7%	2%	**1%**	**6%**
Nalidixic acid	**4%**	0%	0%	**4%**	**0%**	**0%**	0%	0%	**1%**	**0%**	**0%**	0%	0%	**0%**	**0%**	**0%**	0%	0%	**0%**	**0%**
Streptomycin	**26%**	18%	17%	**19%**	**19%**	**17%**	20%	11%	**16%**	**7%**	**24%**	36%	29%	**50%**	**27%**	**30%**	31%	30%	**54%**	**65%**
Tetracycline	**30%**	27%	14%	**19%**	**18%**	**20%**	16%	7%	**13%**	**7%**	**29%**	33%	27%	**50%**	**27%**	**31%**	35%	28%	**53%**	**61%**
Trimethoprim-sulfamethoxazole	**0%**	0%	0%	**0%**	**2%**	**0%**	0%	0%	**1%**	**0%**	**0%**	0%	0%	**0%**	**0%**	**0%**	0%	0%	**2%**	**1%**

For the temporal analyses by province/region, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the previous 5 years and the preceding surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given province/region and antimicrobial.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

For Ontario and the Prairies in 2016, a partial year of retail sampling was conducted due to difficulties in staffing field personnel. As a result, the sampling target and subsequent isolate yields in this province were not achieved and results should be interpreted with caution.

Figure 4. 13 Temporal variations in resistance of *Escherichia coli* isolates from chicken, 2012 to 2016



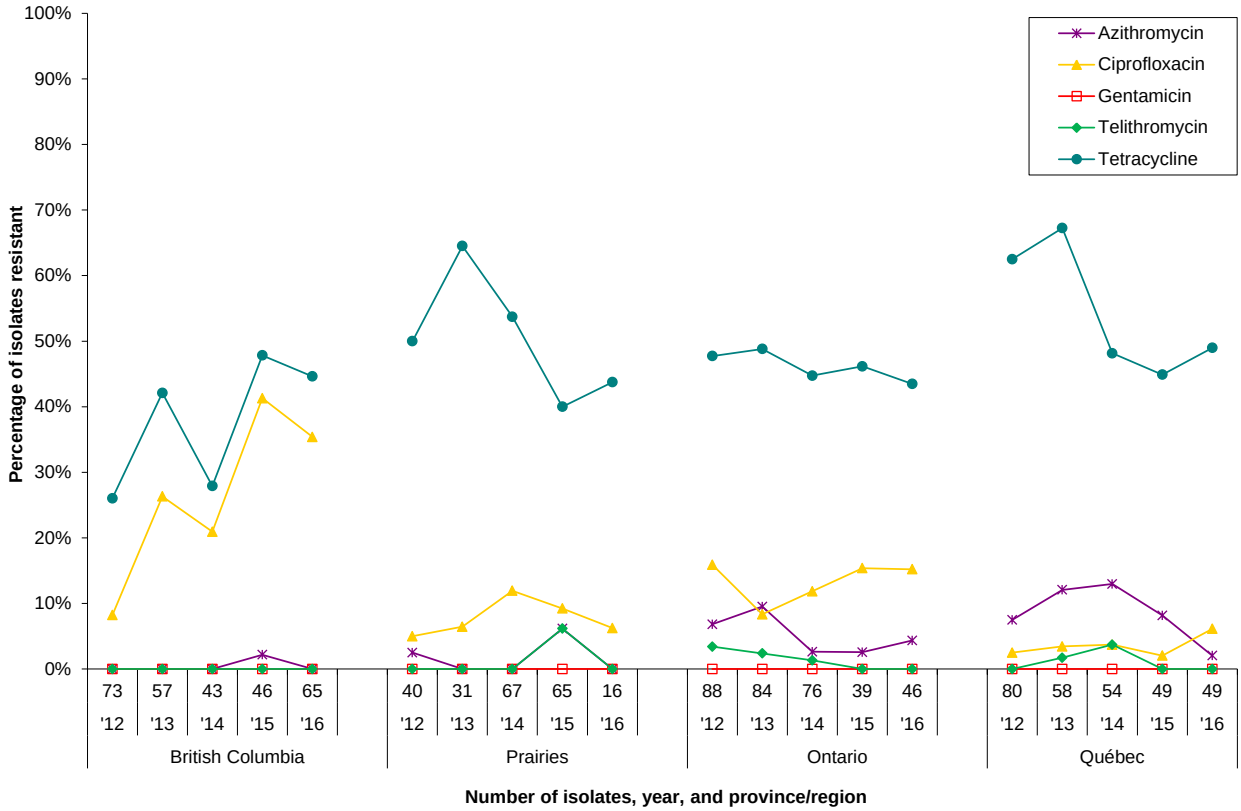
Province/region	British Columbia					Prairies					Ontario					Québec				
Year	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16
Number of isolates	82	65	65	62	81	67	66	109	107	36	107	114	144	69	75	133	117	128	127	118
Antimicrobial																				
Ampicillin	**62%**	74%	69%	**68%**	**58%**	**31%**	35%	39%	**37%**	**39%**	**44%**	37%	33%	**32%**	**19%**	**44%**	54%	43%	**38%**	**41%**
Ceftriaxone	**41%**	60%	48%	**31%**	**17%**	**24%**	23%	20%	**18%**	**8%**	**19%**	24%	11%	**12%**	**4%**	**26%**	25%	18%	**12%**	**8%**
Gentamicin	**12%**	8%	11%	**11%**	**33%**	**9%**	20%	10%	**16%**	**28%**	**12%**	24%	19%	**22%**	**23%**	**24%**	27%	29%	**28%**	**41%**
Nalidixic acid	**5%**	3%	5%	**2%**	**12%**	**7%**	8%	6%	**5%**	**11%**	**2%**	2%	3%	**1%**	**0%**	**2%**	4%	1%	**3%**	**1%**
Streptomycin	**39%**	40%	45%	**61%**	**62%**	**36%**	33%	35%	**34%**	**42%**	**28%**	46%	52%	**38%**	**29%**	**46%**	58%	61%	**60%**	**66%**
Tetracycline	**43%**	49%	35%	**58%**	**59%**	**36%**	44%	41%	**47%**	**36%**	**49%**	54%	56%	**49%**	**37%**	**60%**	61%	59%	**57%**	**62%**
Trimethoprim-sulfamethoxazole	**11%**	11%	8%	**15%**	**16%**	**3%**	3%	7%	**7%**	**3%**	**7%**	21%	9%	**9%**	**9%**	**15%**	26%	21%	**26%**	**27%**

For the temporal analyses by province/region, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the previous 5 years and the preceding surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given province/region and antimicrobial.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

For Ontario and the Prairies in 2016, a partial year of retail sampling was conducted due to difficulties in staffing field personnel. As a result, the sampling target and subsequent isolate yields in this province were not achieved and results should be interpreted with caution.

Figure 4. 14 Temporal variations in resistance of *Campylobacter* isolates from chicken, 2012 to 2016



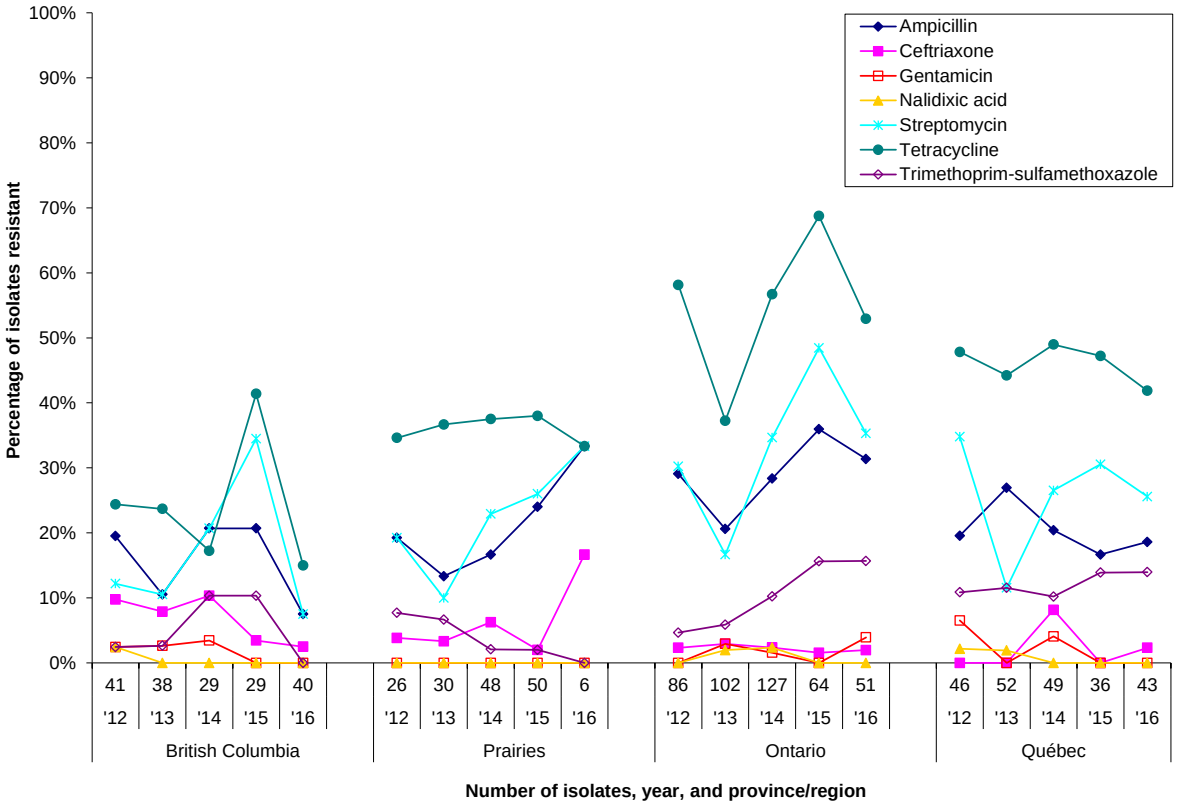
Province/region	British Columbia					Prairies					Ontario					Québec				
Year	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16
Number of isolates	73	57	43	46	65	40	31	67	65	16	88	84	76	39	46	80	58	54	49	49
Antimicrobial																				
Azithromycin	**0%**	0%	0%	**2%**	**0%**	**3%**	0%	0%	**6%**	**0%**	**7%**	10%	3%	**3%**	**4%**	**8%**	12%	13%	**8%**	**2%**
Ciprofloxacin	**8%**	26%	21%	**41%**	**35%**	**5%**	6%	12%	**9%**	**6%**	**16%**	8%	12%	**15%**	**15%**	**3%**	3%	4%	**2%**	**6%**
Gentamicin	**0%**	0%	0%	**0%**	**0%**	**0%**	0%	0%	**0%**	**0%**	**0%**	0%	0%	**0%**	**0%**	**0%**	0%	0%	**0%**	**0%**
Telithromycin	**0%**	0%	0%	**0%**	**0%**	**0%**	0%	0%	**6%**	**0%**	**3%**	2%	1%	**0%**	**0%**	**0%**	2%	4%	**0%**	**0%**
Tetracycline	**26%**	42%	28%	**48%**	**45%**	**50%**	65%	54%	**40%**	**44%**	**48%**	49%	45%	**46%**	**43%**	**63%**	67%	48%	**45%**	**49%**

For the temporal analyses by province/region, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the previous 5 years and the preceding surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given province/region and antimicrobial.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

For Ontario and the Prairies in 2016, a partial year of retail sampling was conducted due to difficulties in staffing field personnel. As a result, the sampling target and subsequent isolate yields in this province were not achieved and results should be interpreted with caution.

Figure 4. 15 Temporal variations in resistance of *Escherichia coli* isolates from pork, 2012 to 2016



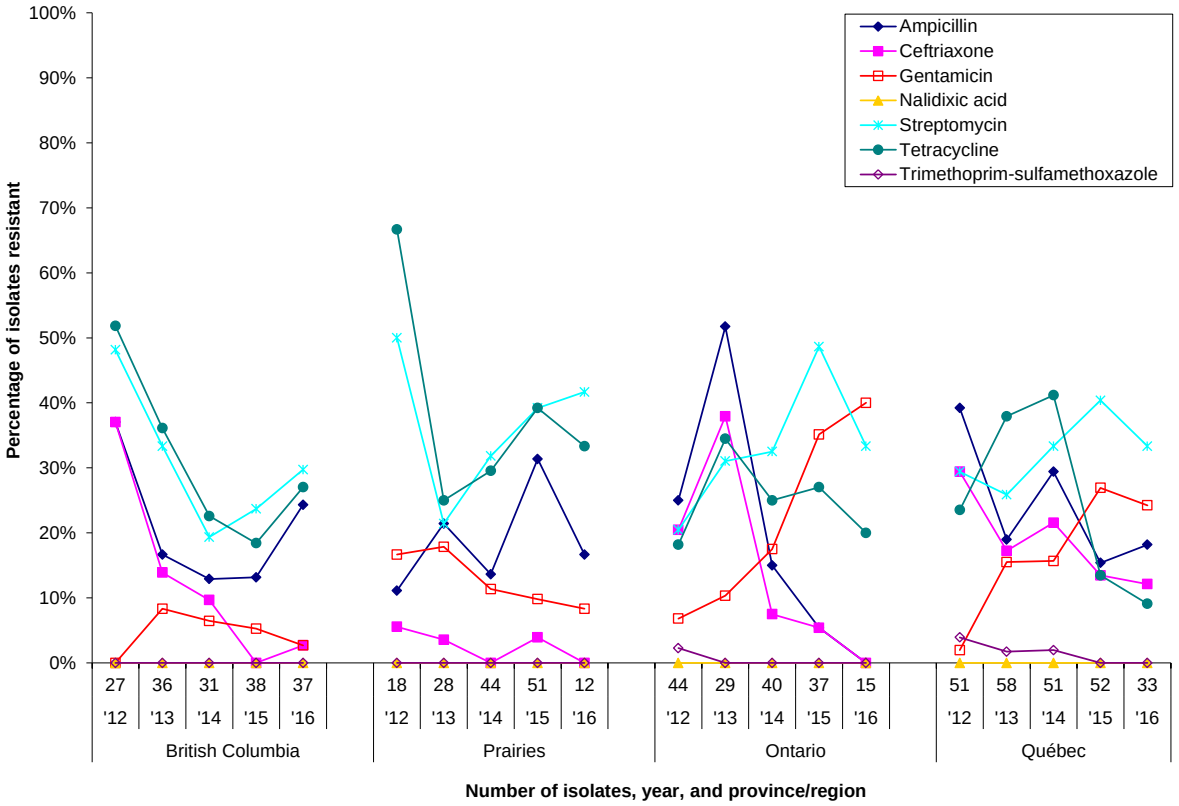
Province/region	British Columbia					Prairies					Ontario					Québec				
Year	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16
Number of isolates	41	38	29	29	40	26	30	48	50	6	86	102	127	64	51	46	52	49	36	43
Antimicrobial																				
Ampicillin	**20%**	11%	21%	**21%**	**8%**	**19%**	13%	17%	**24%**	**33%**	**29%**	21%	28%	**36%**	**31%**	**20%**	27%	20%	**17%**	**19%**
Ceftriaxone	**10%**	8%	10%	**3%**	**3%**	**4%**	3%	6%	**2%**	**17%**	**2%**	3%	2%	**2%**	**2%**	**0%**	0%	8%	**0%**	**2%**
Gentamicin	**2%**	3%	3%	**0%**	**0%**	**0%**	0%	0%	**0%**	**0%**	**0%**	3%	2%	**0%**	**4%**	**7%**	0%	4%	**0%**	**0%**
Nalidixic acid	**2%**	0%	0%	**0%**	**0%**	**0%**	0%	0%	**0%**	**0%**	**0%**	2%	2%	**0%**	**0%**	**2%**	2%	0%	**0%**	**0%**
Streptomycin	**12%**	11%	21%	**34%**	**8%**	**19%**	10%	23%	**26%**	**33%**	**30%**	17%	35%	**48%**	**35%**	**35%**	12%	27%	**31%**	**26%**
Tetracycline	**24%**	24%	17%	**41%**	**15%**	**35%**	37%	38%	**38%**	**33%**	**58%**	37%	57%	**69%**	**53%**	**48%**	44%	49%	**47%**	**42%**
Trimethoprim-sulfamethoxazole	**2%**	3%	10%	**10%**	**0%**	**8%**	7%	2%	**2%**	**0%**	**5%**	6%	10%	**16%**	**16%**	**11%**	12%	10%	**14%**	**14%**

For the temporal analyses by province/region, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the previous 5 years and the preceding surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given province/region and antimicrobial.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

For Ontario and the Prairies in 2016, a partial year of retail sampling was conducted due to difficulties in staffing field personnel. As a result, the sampling target and subsequent isolate yields in this province were not achieved and results should be interpreted with caution.

Figure 4. 16 Temporal variations in resistance of *Salmonella* isolates from turkey, 2012 to 2016



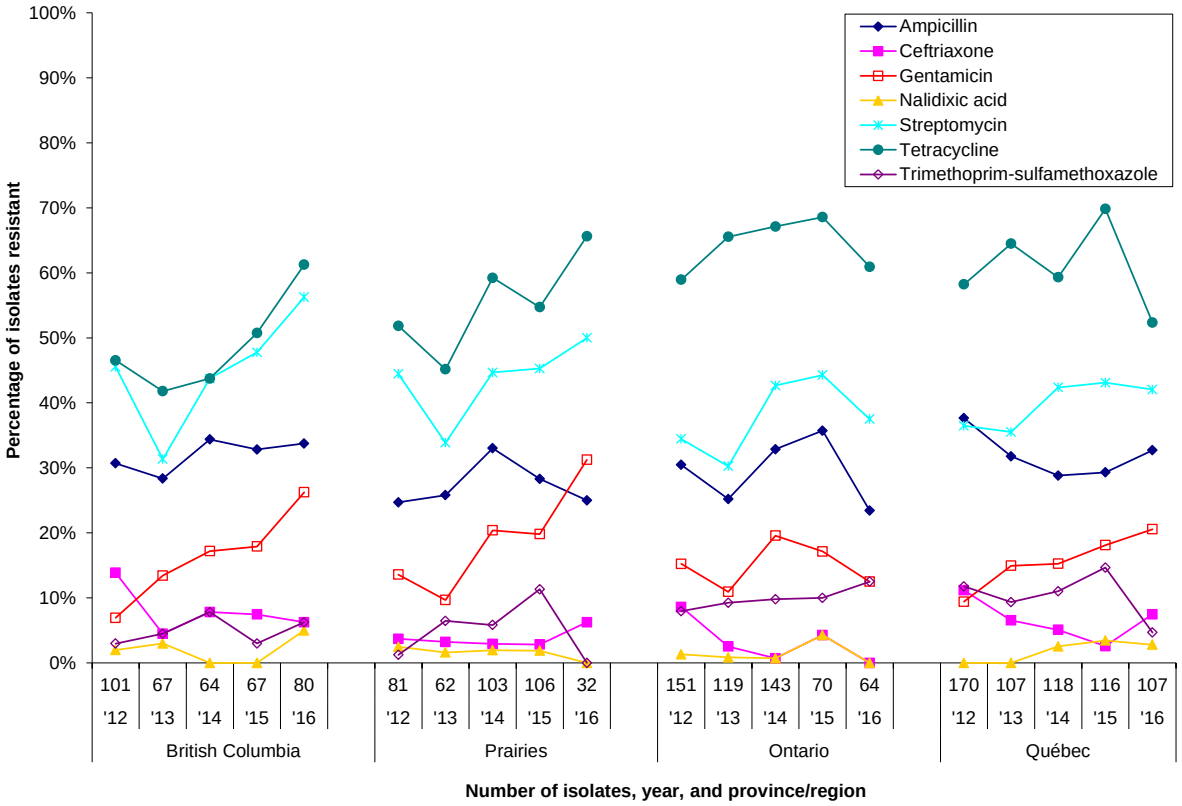
Province/region	British Columbia					Prairies					Ontario					Québec				
Year	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16
Number of isolates	27	36	31	38	37	18	28	44	51	12	44	29	40	37	15	51	58	51	52	33
Antimicrobial																				
Ampicillin	**37%**	17%	13%	**13%**	**24%**	**11%**	21%	14%	**31%**	**17%**	**25%**	52%	15%	**5%**	**0%**	**39%**	19%	29%	**15%**	**18%**
Ceftriaxone	**37%**	14%	10%	**0%**	**3%**	**6%**	4%	0%	**4%**	**0%**	**20%**	38%	8%	**5%**	**0%**	**29%**	17%	22%	**13%**	**12%**
Gentamicin	**0%**	8%	6%	**5%**	**3%**	**17%**	18%	11%	**10%**	**8%**	**7%**	10%	18%	**35%**	**40%**	**2%**	16%	16%	**27%**	**24%**
Nalidixic acid	**0%**	0%	0%	**0%**	**0%**	**0%**	0%	0%	**0%**	**0%**	**0%**	0%	0%	**0%**	**0%**	**0%**	0%	0%	**0%**	**0%**
Streptomycin	**48%**	33%	19%	**24%**	**30%**	**50%**	21%	32%	**39%**	**42%**	**20%**	31%	33%	**49%**	**33%**	**29%**	26%	33%	**40%**	**33%**
Tetracycline	**52%**	36%	23%	**18%**	**27%**	**67%**	25%	30%	**39%**	**33%**	**18%**	34%	25%	**27%**	**20%**	**24%**	38%	41%	**13%**	**9%**
Trimethoprim-sulfamethoxazole	**0%**	0%	0%	**0%**	**0%**	**0%**	0%	0%	**0%**	**0%**	**2%**	0%	0%	**0%**	**0%**	**4%**	2%	2%	**0%**	**0%**

For the temporal analyses by province/region, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the previous 5 years and the preceding surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given province/region and antimicrobial.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

For Ontario and the Prairies in 2016, a partial year of retail sampling was conducted due to difficulties in staffing field personnel. As a result, the sampling target and subsequent isolate yields in this province were not achieved and results should be interpreted with caution.

Figure 4. 17 Temporal variations in resistance of *Escherichia coli* isolates from turkey, 2012 to 2016



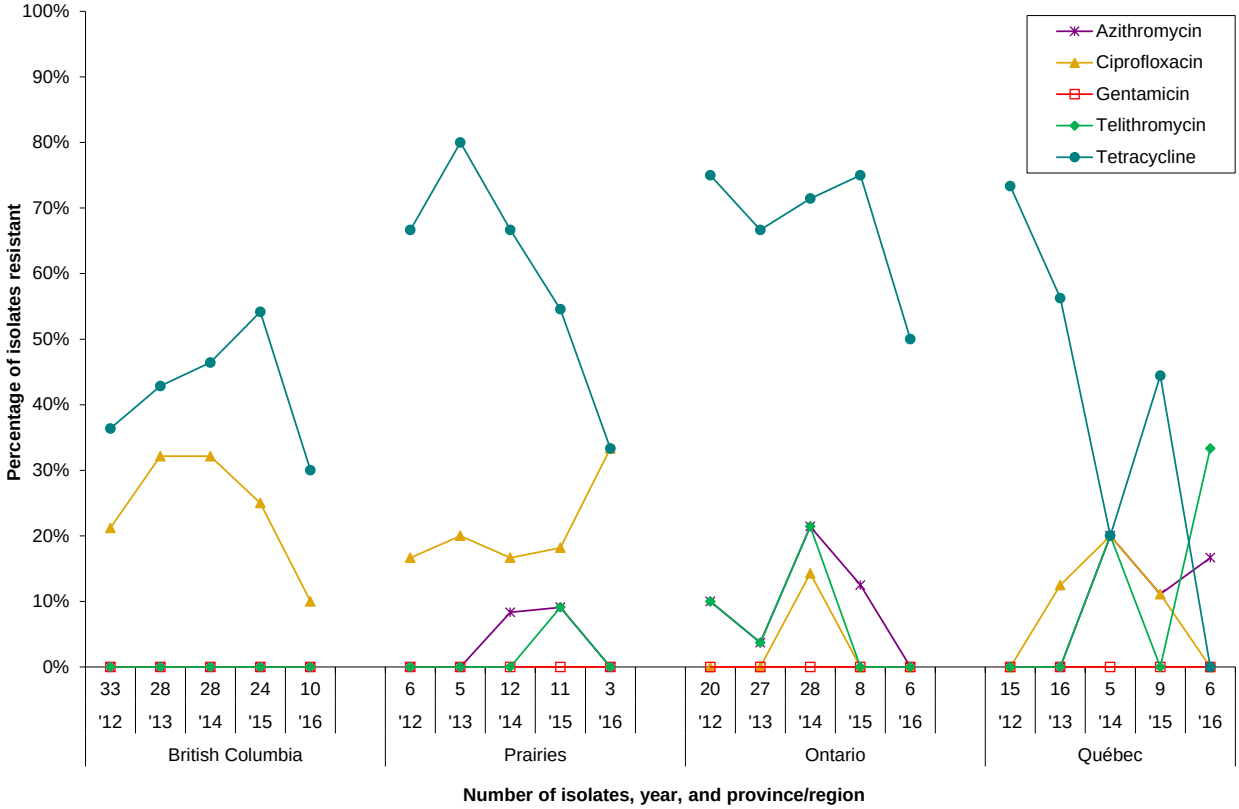
Province/region	British Columbia					Prairies					Ontario					Québec				
Year	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16
Number of isolates	101	67	64	67	80	81	62	103	106	32	151	119	143	70	64	170	107	118	116	107
Antimicrobial																				
Ampicillin	**31%**	28%	34%	**33%**	**34%**	**25%**	26%	33%	**28%**	**25%**	**30%**	25%	33%	**36%**	**23%**	**38%**	32%	29%	**29%**	**33%**
Ceftriaxone	**14%**	4%	8%	**7%**	**6%**	**4%**	3%	3%	**3%**	**6%**	**9%**	3%	1%	**4%**	**0%**	**11%**	7%	5%	**3%**	**7%**
Gentamicin	**7%**	13%	17%	**18%**	**26%**	**14%**	10%	20%	**20%**	**31%**	**15%**	11%	20%	**17%**	**13%**	**9%**	15%	15%	**18%**	**21%**
Nalidixic acid	**2%**	3%	0%	**0%**	**5%**	**2%**	2%	2%	**2%**	**0%**	**1%**	1%	1%	**4%**	**0%**	**0%**	0%	3%	**3%**	**3%**
Streptomycin	**46%**	31%	44%	**48%**	**56%**	**44%**	34%	45%	**45%**	**50%**	**34%**	30%	43%	**44%**	**38%**	**36%**	36%	42%	**43%**	**42%**
Tetracycline	**47%**	42%	44%	**51%**	**61%**	**52%**	45%	59%	**55%**	**66%**	**59%**	66%	67%	**69%**	**61%**	**58%**	64%	59%	**70%**	**52%**
Trimethoprim-sulfamethoxazole	**3%**	4%	8%	**3%**	**6%**	**1%**	6%	6%	**11%**	**0%**	**8%**	9%	10%	**10%**	**13%**	**12%**	9%	11%	**15%**	**5%**

For the temporal analyses by province/region, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the previous 5 years and the preceding surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given province/region and antimicrobial.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

For Ontario and the Prairies in 2016, a partial year of retail sampling was conducted due to difficulties in staffing field personnel. As a result, the sampling target and subsequent isolate yields in this province were not achieved and results should be interpreted with caution.

Figure 4. 18 Temporal variations in resistance of *Campylobacter* isolates from turkey, 2012 to 2016



Province/region	British Columbia					Prairies					Ontario					Québec				
Year	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16
Number of isolates	33	28	28	24	10	6	5	12	11	3	20	27	28	8	6	15	16	5	9	6
Antimicrobial																				
Azithromycin	**0%**	0%	0%	**0%**	**0%**	**0%**	0%	8%	**9%**	**0%**	**10%**	4%	21%	**13%**	**0%**	**0%**	0%	20%	**11%**	**17%**
Ciprofloxacin	**21%**	32%	32%	**25%**	**10%**	**17%**	20%	17%	**18%**	**33%**	**0%**	0%	14%	**0%**	**0%**	**0%**	13%	20%	**11%**	**0%**
Gentamicin	**0%**	0%	0%	**0%**	**0%**	**0%**	0%	0%	**0%**	**0%**	**0%**	0%	0%	**0%**	**0%**	**0%**	0%	0%	**0%**	**0%**
Telithromycin	**0%**	0%	0%	**0%**	**0%**	**0%**	0%	0%	**9%**	**0%**	**10%**	4%	21%	**0%**	**0%**	**0%**	0%	20%	**0%**	**33%**
Tetracycline	**36%**	43%	46%	**54%**	**30%**	**67%**	80%	67%	**55%**	**33%**	**75%**	67%	71%	**75%**	**50%**	**73%**	56%	20%	**44%**	**0%**

For the temporal analyses by province/region, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the previous 5 years and the preceding surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given province/region and antimicrobial.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

For Ontario and the Prairies in 2016, a partial year of retail sampling was conducted due to difficulties in staffing field personnel. As a result, the sampling target and subsequent isolate yields in this province were not achieved and results should be interpreted with caution.

Recovery results

Table 4. 10 Retail Meat Surveillance recovery rates, 2003 to 2016

Animal species	Province / region	Year	Percentage (%) of isolates recovered and number of isolates recovered / number of samples submitted					
			Escherichia coli		*Salmonella*		*Campylobacter*		*Enterococcus*	
Beef	British Columbia	2005	**93%**	27/29						
		2007	**79%**	49/62						
		2008	**77%**	88/115						
		2009	**71%**	79/112						
		2010	**51%**	64/125						
		2011	**53%**	57/107						
		2012	**60%**	76/126						
		2013	**47%**	40/85						
		2014	**43%**	43/100						
		2015	**42%**	45/108						
		2016	**45%**	59/130						
	Prairies	2005	**79%**	120/151						
		2006	**76%**	123/161						
		2007	**78%**	118/151						
		2008	**76%**	134/177						
		2009	**83%**	135/163						
		2010	**80%**	107/134						
		2011[a]	**75%**	54/72						
		2012	**75%**	80/107						
		2013	**53%**	48/90						
		2014	**53%**	97/184						
		2015	**46%**	86/186						
		2016	**62%**	48/78						
	Ontario	2003	**66%**	101/154	**2%**	2/84	**3%**	2/76	**91%**	69/76
		2004	**80%**	190/237						
		2005	**81%**	184/227						
		2006	**81%**	189/235						
		2007	**71%**	184/227						
		2008	**78%**	185/236						
		2009	**79%**	195/248						
		2010	**69%**	123/177						
		2011	**73%**	161/222						
		2012	**63%**	110/176						
		2013	**58%**	104/180						
		2014	**51%**	121/236						
		2015	**46%**	53/116						
		2016	**56%**	68/122						
	Québec	2003	**57%**	84/147	**0%**	0/33	**0%**	0/33	**80%**	28/35
		2004	**56%**	137/245						
		2005	**56%**	126/225						
		2006	**50%**	109/215						
		2007	**68%**	147/216						
		2008	**59%**	126/214						
		2009	**54%**	108/201						
		2010	**46%**	102/223						
		2011	**45%**	91/204						
		2012	**51%**	107/219						
		2013	**42%**	74/175						
		2014	**41%**	85/207						
		2015	**39%**	79/203						
		2016	**43%**	82/192						

See corresponding footnotes at the end of the table.

Table 4. 10 Retail Meat Surveillance recovery rates, 2003 to 2016 (continued)

Animal species	Province / region	Year	Percentage (%) of isolates recovered and number of isolates recovered / number of samples submitted							
			Escherichia coli		*Salmonella*		*Campylobacter*		*Enterococcus*	
	Atlantic	2004	**67%**	16/24						
		2007	**52%**	16/31						
		2008	**70%**	39/56						
		2009	**69%**	137/200						
		2010	**69%**	126/183						
		2011	**58%**	110/191						
		2012[d]	**50%**	24/48						
		2013	**58%**	83/143						
		2014	**57%**	118/207						
		2015[e]								
		2016[e]								
Chicken	British Columbia	2005	**95%**	19/20	**13%**	5/39	**69%**	27/39	**100%**	20/20
		2007	**98%**	42/43	**22%**[b]	18/81	**35%**	28/80	**100%**	34/34
		2008	**90%**	70/78	**32%**	47/145	**34%**	50/145	**100%**	78/78
		2009	**95%**	70/74	**40%**	59/146	**53%**	78/146	**97%**	72/74
		2010	**89%**	75/84	**34%**	56/166	**42%**	70/166		
		2011	**96%**	70/73	**45%**	64/143	**50%**	71/143		
		2012	**99%**	82/83	**32%**	53/166	**44%**	73/166		
		2013	**95%**	57/60	**24%**	28/118	**42%**	50/118		
		2014	**98%**	65/66	**27%**	36/133	**32%**	43/133		
		2015	**91%**	62/68	**51%**	69/136	**35%**	47/136		
		2016	**94%**	82/87	**36%**	62/173	**38%**	65/172		
	Prairies	2005	**98%**	81/83	**14%**	21/153	**37%**	53/145	**98%**	83/85
		2006	**98%**	85/86	**16%**	25/153	**33%**	51/155	**98%**	85/87
		2007	**97%**	75/77	**31%**[b]	43/141	**35%**	49/141	**100%**	77/77
		2008	**99%**	91/92	**40%**	64/161	**25%**	41/161	**100%**	92/92
		2009	**98%**	90/92	**47%**	71/150	**32%**	48/150	**100%**	92/92
		2010	**90%**	71/79	**32%**	42/132	**28%**	37/132		
		2011[a]	**97%**	38/39	**40%**	29/73	**34%**	25/73		
		2012	**94%**	67/71	**33%**	46/140	**29%**	40/140		
		2013	**97%**	58/60	**32%**	38/120	**20%**	24/120		
		2014	**97%**	109/112	**36%**	81/222	**30%**	67/222		
		2015	**95%**	107/113	**35%**	77/220	**30%**	65/220		
		2016	**90%**	36/40	**37%**	28/76	**21%**	16/76		
	Ontario	2003	**95%**	137/144	**16%**	27/167	**47%**	78/166	**99%**	143/144
		2004	**95%**	150/158	**17%**	54/315	**45%**	143/315	**100%**	158/158
		2005	**95%**	145/153	**9%**	26/303	**40%**	120/303	**99%**	150/152
		2006	**97%**	152/156	**12%**	36/311	**34%**	104/311	**98%**	154/156
		2007	**98%**	157/161	**54%**[b]	172/320	**37%**	117/320	**100%**	161/161
		2008	**96%**	150/156	**45%**	139/311	**39%**	121/311	**99%**	154/156
		2009	**95%**	155/164	**43%**	142/328	**31%**	101/328	**100%**	164/164
		2010	**86%**	100/116	**39%**	90/232	**28%**	64/232		
		2011	**93%**	137/147	**40%**	119/294	**24%**	71/293		
		2012	**92%**	107/116	**44%**	102/232	**39%**	87/226		
		2013	**93%**	110/118	**39%**	89/231	**35%**	83/234		
		2014	**92%**	144/157	**24%**	75/312	**25%**	78/312		
		2015	**91%**	69/76	**17%**	26/151	**26%**	40/151		
		2016	**93%**	75/81	**14%**	22/160	**29%**	46/160		

See corresponding footnotes at the end of the table.

Table 4. 10 Retail Meat Surveillance recovery rates, 2003 to 2016 (continued)

Animal species	Province / region	Year	Percentage (%) of isolates recovered and number of isolates recovered / number of samples submitted							
			Escherichia coli		*Salmonella*		*Campylobacter*		*Enterococcus*	
	Québec	2003	**89%**	112/126	**16%**	29/171	**55%**	94/170	**100%**	125/125
		2004	**96%**	157/161	**17%**	53/320	**50%**	161/322	**100%**	161/161
		2005	**95%**	142/149	**9%**	26/300	**34%**	103/299	**100%**	150/150
		2006	**94%**	135/144	**12%**	33/288	**35%**	100/288	**100%**	144/144
		2007	**90%**	129/144	**40%**[b]	113/287	**21%**	59/287	**99%**	143/144
		2008	**91%**	131/144	**42%**	120/287	**19%**	54/287	**100%**	144/144
		2009	**94%**	126/134	**39%**	105/267	**20%**	52/266	**99%**	132/134
		2010	**93%**	138/148	**39%**	116/296	**21%**	63/296		
		2011	**99%**	134/136	**37%**	100/272	**21%**	57/272		
		2012	**95%**	133/140	**38%**	106/280	**28%**	78/274		
		2013	**90%**	105/117	**37%**	89/243	**23%**	55/243		
		2014	**93%**	129/138	**33%**	92/276	**20%**	54/276		
		2015	**93%**	127/136	**40%**	109/272	**18%**	49/272		
		2016	**92%**	118/128	**28%**	71/256	**19%**	49/254		
	Atlantic	2004	**100%**	13/13	**4%**	1/25	**40%**	10/25	**100%**	13/13
		2007[c]	**91%**	29/32	**22%**[b]	7/32				
		2008[c]	**68%**	38/56	**22%**	12/56				
		2009[c]	**94%**	187/199	**49%**	97/199	**29%**	57/199		
		2010	**93%**	176/190	**41%**	77/190	**37%**	70/190		
		2011	**89%**	171/192	**28%**	53/192	**30%**	57/192		
		2012[d]	**96%**	46/48	**23%**	11/48	**21%**	10/48		
		2013	**92%**	133/144	**31%**	44/144	**47%**	67/144		
		2014	**86%**	179/207	**31%**	64/207	**25%**	52/206		
		2015[e]								
		2016[e]								
Pork	British Columbia	2005	**31%**	10/32						
		2007	**29%**	23/79	**1%**	1/79				
		2008	**30%**	44/148	**2%**	3/148				
		2009	**26%**	38/145	**1%**	2/145				
		2010	**19%**	31/166	**1%**	2/167				
		2011	**27%**	49/180	**2%**	3/180				
		2012	**25%**	41/167	**0%**	0/167				
		2013	**28%**	33/118	**0%**	0/118				
		2014	**22%**	29/131	**2%**	2/132				
		2015	**21%**	29/136						
		2016	**23%**	40/172						
	Prairies	2005	**30%**	48/162						
		2006	**30%**	49/165	**2%**	3/134				
		2007	**25%**	38/154	**2%**	3/154				
		2008	**23%**	41/176	**1%**	1/176				
		2009	**18%**	29/164	**0%**	0/164				
		2010	**12%**	17/142	**1%**	1/142				
		2011[a]	**11%**	10/90	**1%**	1/90				
		2012	**19%**	26/140	**1%**	2/141				
		2013	**24%**	28/119	**3%**	3/120				
		2014	**22%**	48/223	**1%**	3/223				
		2015	**23%**	50/220						
		2016	**8%**	6/78						

See corresponding footnotes at the end of the table.

Table 4. 10 Retail Meat Surveillance recovery rates, 2003 to 2016 (continued)

Animal species	Province / region	Year	Percentage (%) of isolates recovered and number of isolates recovered / number of samples submitted							
			Escherichia coli		*Salmonella*		*Campylobacter*		*Enterococcus*	
	Ontario	2003	**58%**	90/154	**1%**	1/93	**0%**	0/76	**87%**	66/76
		2004	**71%**	198/279						
		2005	**59%**	179/303						
		2006	**59%**	182/311	**< 1%**	1/255				
		2007	**54%**	172/320	**2%**	6/319				
		2008	**50%**	155/312	**2%**	7/310				
		2009	**41%**	136/328	**2%**	8/327				
		2010	**38%**	84/224	**0%**	0/224				
		2011	**42%**	155/371	**2%**	6/370				
		2012	**37%**	86/231	**2%**	5/231				
		2013	**43%**	100/233	**1%**	3/232				
		2014	**41%**	127/312	**2%**	6/312				
		2015	**42%**	64/152						
		2016	**32%**	51/160						
	Québec	2003	**42%**	61/147	**3%**	1/32	**9%**	3/32	**82%**	28/34
		2004	**38%**	109/290						
		2005	**26%**	79/300						
		2006	**20%**	57/287	**0%**	0/232				
		2007	**22%**	64/287	**1%**	3/288				
		2008	**21%**	60/287	**2%**	5/286				
		2009	**15%**	41/268	**1%**	3/268				
		2010	**16%**	47/296	**1%**	4/296				
		2011	**32%**	122/387	**4%**	17/387				
		2012	**16%**	46/279	**3%**	8/279				
		2013	**20%**	48/239	**<1%**	1/239				
		2014	**18%**	49/276	**<1%**	2/276				
		2015	**13%**	36/272						
		2016	**17%**	43/256						
	Atlantic	2004	**58%**	14/24						
		2007	**39%**	13/31	**3%**	1/30				
		2008	**30%**	17/56	**2%**	1/56				
		2009	**41%**	82/200	**3%**	5/199				
		2010	**39%**	74/190	**4%**	8/190				
		2011	**43%**	95/223	**3%**	7/221				
		2012[d]	**25%**	12/48	**0%**	0/48				
		2013	**40%**	57/143	**1%**	2/142				
		2014	**41%**	86/209	**6%**	13/208				
		2015[e]								
		2016[e]								

See corresponding footnotes at the end of the table.

Table 4. 10 Retail Meat Surveillance recovery rates, 2003 to 2016 (continued)

Animal species	Province / region	Year	Percentage (%) of isolates recovered and number of isolates recovered / number of samples submitted							
			Escherichia coli		*Salmonella*		*Campylobacter*		*Enterococcus*	
Turkey	British Columbia	2011	**97%**	59/61	**11%**	8/71	**24%**	17/71		
		2012	**97%**	101/104	**18%**	27/153	**22%**	33/153		
		2013	**98%**	59/60	**26%**	30/115	**22%**	25/115		
		2014	**97%**	64/66	**25%**	31/122	**23%**	28/122		
		2015	**99%**	67/68	**32%**	38/118	**20%**	24/118		
		2016	**94%**	80/85	**24%**	36/152	**7%**	10/153		
	Prairies	2011[a]	**100%**	10/10	**20%**	2/10	**10%**	1/10		
		2012	**91%**	81/89	**14%**	18/128	**5%**	6/128		
		2013	**90%**	56/62	**23%**	25/107	**4%**	4/105		
		2014	**93%**	103/111	**22%**	44/196	**7%**	13/196		
		2015	**99%**	106/107	**31%**	51/165	**7%**	11/165		
		2016	**97%**	32/33	**29%**	12/41	**7%**	3/41		
	Ontario	2011	**95%**	162/171	**14%**	27/191	**9%**	18/191		
		2012	**97%**	152/156	**20%**	44/223	**9%**	20/223		
		2013	**95%**	115/121	**12%**	28/228	**12%**	27/227		
		2014	**92%**	143/156	**13%**	40/310	**9%**	28/310		
		2015	**92%**	70/76	**24%**	37/152	**5%**	8/152		
		2016	**81%**	64/79	**9%**	15/158	**4%**	6/158		
	Québec	2011	**91%**	138/152	**17%**	27/163	**10%**	16/163		
		2012	**96%**	170/178	**21%**	51/246	**6%**	15/246		
		2013	**89%**	98/110	**32%**	57/177	**9%**	16/178		
		2014	**86%**	119/138	**19%**	51/262	**2%**	5/262		
		2015	**86%**	116/135	**21%**	52/247	**4%**	9/247		
		2016	**84%**	107/128	**14%**	33/238	**3%**	6/237		
	Atlantic	2013	**85%**	107/126	**19%**	24/126	**23%**	29/124		
		2014	**76%**	143/187	**12%**	23/187	**8%**	15/185		
		2015[e]								
		2016[e]								

Grey-shaded areas indicate either: a) isolates recovered from sampling activities outside the scope of CIPARS routine (or "core") surveillance in the specified year (i.e. grey-shaded areas with data) or b) discontinuation or no surveillance activity (i.e. grey-shaded areas with no data).

The Prairies is a region including the provinces Alberta and Saskatchewan.

For Ontario and the Prairies in 2016, a partial year of retail sampling was conducted due to difficulties in staffing field personnel. As a result, the sampling target and subsequent isolate yields in this province were not achieved and results should be interpreted with caution.

The Atlantic region includes New Brunswick, Nova Scotia, and Prince Edward Island.

[a] In 2011, due to an unforeseeable pause in retail sampling in Saskatchewan of approximately 3 months, the expected number of samples was not met and thus, results for the Prairies for this year should be interpreted with caution.

[b] Enhancement to the *Salmonella* recovery method yielded higher recovery rates from retail chicken in 2007 than in prior years.

[c] For the Atlantic region, recovery results are not presented for *Campylobacter* in 2007 and 2008 as well as for Enterococcus in 2007, 2008, and 2009 due to concerns regarding harmonization of laboratory methods.

[d] Due to an unforeseeable pause in retail sampling in the Atlantic region from April through December in 2012, the expected number of samples was not achieved and thus, results for this region in 2012 are not representative and potentially lack the precision necessary to be included as regular surveillance data. For this reason, these data are not presented anywhere else in this chapter.

[e] No retail sampling was conducted in the Atlantic region in 2015 or 2016.

Abattoir Surveillance

Key findings

A summary of Abattoir Surveillance recovery rates are presented in Table 4. 19.

Beef cattle

Escherichia coli (n = 133)

In 2016, no isolates were resistant to ceftriaxone. Four isolates (3%, 4/133) were resistant to nalidixic acid. No isolates were resistant to Category I antimicrobials. Four (3%, 4/133) isolates were resistant to 4 antimicrobials (CHL-SSS-STR-TET [3 isolates], CHL-NAL-SSS-TET with intermediate resistance to CIP [1 isolate]) and 1 isolate (1%, 1/133) was resistant to 5 antimicrobials (AMP-CHL-SSS-STR-TET) (Table 4. 11).

Campylobacter (n = 104)

One *C. coli* isolate (1%, 1/104) was resistant to 5 classes of antimicrobials in 2016 (AZM-CLI-ERY-TEL-TET). Fifteen isolates (14%, 15/104) were resistant to ciprofloxacin and nalidixic acid in 2016 (Table 4. 12).

There was a significant increase in resistance between 2012 and 2016 for azithromycin (0%, 0/152 in 2012; 5%, 5/104 in 2016) and telithromycin (0%, 0/152 in 2012; 5%, 5/104 in 2016). There was also a significant increase in resistance to ciprofloxacin in 2016 (15/104, 14%) when compared to both 2012 (5%, 8/152) and 2015 (5%, 7/129) (Figure 4. 20).

Chickens

Salmonella (n = 120)

In 2016, all Enteritidis isolates (100%, 29/29) were susceptible to all antimicrobials tested. One Kentucky (1/41; 2%, AMC-AMP-CRO-FOX-GEN-SSS-STR-TET) and 2 Infantis (22%, 2/9; AMC-AMP-CHL-CRO-FOX-GEN-SSS-STR-TET) isolates were resistant to 4 and 5 classes of antimicrobials, respectively (Table 4. 13).

There was a significant decrease in the proportion of isolates resistant to ceftriaxone in 2016 (9% 11/120) when compared to 2012 (20%, 25/126). The proportion of isolates resistant to ampicillin was significantly lower in 2016 (9%, 11/120) than in 2012 (24%, 30/126), 2007 (18%, 37/206), and 2003 (25%, 32/126). The proportion of isolates resistant to gentamicin was significantly higher in 2016 (5%, 6/120) than in 2007 (0%, 0/206) and 2012 (0%, 0/126) (Figure 4. 21).

Escherichia coli (n = 207)

One isolate was resistant to 6 classes of antimicrobials (AMC-AMP-CHL-CRO-FOX-NAL-SSS-STR-TET) (Table 4. 14).

The proportion of isolates resistant to ceftriaxone was significantly lower in 2016 (10%, 20/207) compared to 2012 (18%, 32/173), 2007 (26%, 47/180), and 2003 (20%, 31/153%). There was a significant increase in the proportion of isolates resistant to gentamicin in 2016

(19%, 40/207) compared to 2007 (11%, 20/180). There was also a significant increase in resistance to streptomycin and trimethoprim-sulfamethoxazole in 2016 (58%, 121/207 and 17%, 35/207, respectively) compared to 2007 (40%, 72/180 and 4%, 8/180, respectively) (Figure 4. 22).

Campylobacter (n = 177)

Three isolates (2%, 3/177) (1 *C. jejuni*, 2 *C. coli*) were resistant to 4 classes of antimicrobials. All had the AZM-CLI-ERY-TEL-TET resistance pattern (Table 4. 15).

The proportion of isolates resistant to ciprofloxacin was significantly higher in 2016 (15%, 26/177) than in 2012 (7%, 11/155) (Figure 4. 23).

Pigs

Salmonella (n = 187)[68]

Derby (19%, 36/187), Typhimurium (13%, 24/187), and Infantis (12%, 22/187) were the most common serovars found in *Salmonella* from pigs. Three isolates (1 S. Ohio var 14+, AMC-AMP-AZM-CHL-CRO-FOX-GEN-SSS-STR-SXT-TET; 1 Ohio, AMP-AZM-CHL-GEN-SSS-STR-SXT-TET; 1 Ohio AMP-AZM-CHL-SSS-STR-SXT-TET) were resistant to 6 classes of antimicrobials (Table 4. 16).

The proportion of isolates resistant to ampicillin, streptomycin, and tetracycline were significantly lower in 2016 (18%, 34/188; 32%, 61/188; and 40%, 75/188, respectively) than in 2007 (29%, 30/105; 45%, 47/105; and 55%, 58/105, respectively) (Figure 4. 24).

Escherichia coli (n = 182)

Nineteen isolates (10%, 19/182) were resistant to 4 classes of antimicrobials and 6 isolates (3%, 6/182) were resistant to 5 classes of antimicrobials (Table 4. 17).

Campylobacter (n = 265)

Seventy isolates (26%, 70/265) were resistant to 4 classes of antimicrobials and 9 isolates (3%, 9/265) were resistant to 5 classes of antimicrobials (Table 4. 18).

The proportion of isolates resistant to ciprofloxacin returned to historical levels and was significantly higher in 2016 (13%, 35/265) than in 2015 (6%, 16/279) (Figure 4. 26).

[68] The disparity between the total number of isolates reported in the temporal figure (n = 188) and multiclass resistance table (n = 187) is due to missing serotyping information.

Multiclass resistance

Table 4. 11 Number of antimicrobial classes in resistance patterns of *Escherichia coli* from beef cattle, 2016

Animal species	Number of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial											
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
Beef cattle	133	77	31	20	5			24	4					24			6		4	48

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

Table 4. 12 Number of antimicrobial classes in resistance patterns of *Campylobacter* from beef cattle, 2016

Species	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial							
							Aminoglycosides	Ketolides	Lincosamides	Macrolides		Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	TEL	CLI	AZM	ERY	FLR	CIP	NAL	TET
Campylobacter jejuni	73 (70.2)	21	38	14									14	14	52
Campylobacter coli	31 (29.8)	7	18	5	1			5	5	5	5		1	1	20
Total	**104 (100)**	**28**	**56**	**19**	**1**			**5**	**5**	**5**	**5**		**15**	**15**	**72**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

Table 4. 13 Number of antimicrobial classes in resistance patterns of *Salmonella* from chickens, 2016

Serovar	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial											
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
Kentucky	41 (34.2)	1	4	35	1		1	39	4	4	4	4		1						40
Enteritidis	29 (24.2)	29																		
Infantis	15 (12.5)	12	1		2		2	3	3	3	3	3		2			2			2
Heidelberg	11 (9.2)	5	3	3			2	4	2	2	2	2		3	1					1
Livingstone	3 (2.5)		3																	3
Less common serovars	21 (17.5)	11	3	7			1	8	2	2	2	2		5	1					8
Total	**120 (100)**	**58**	**14**	**45**	**3**		**6**	**54**	**11**	**11**	**11**	**11**		**11**	**2**		**2**			**54**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

Serovars represented by less than 2% of isolates were classified as “Less common serovars”.

Table 4. 14 Number of antimicrobial classes in resistance patterns of *Escherichia coli* from chickens, 2016

Animal species	Number of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial												
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
Chickens	207	51	23	100	32	1	40	121	76	22	20	21		99	35	1	13	1	12	100

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

Table 4. 15 Number of antimicrobial classes in resistance patterns of *Campylobacter* from chickens, 2016

Species	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial							
							Aminoglycosides	Ketolides	Lincosamides	Macrolides		Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	TEL	CLI	AZM	ERY	FLR	CIP	NAL	TET
Campylobacter jejuni	156 (88.1)	84	58	13	1			2	1	3	3		16	16	67
Campylobacter coli	20 (11.3)	6	6	6	2			2	3	4	4		9	9	8
Campylobacter spp.	1 (0.6)		1										1	1	
Total	**177 (100)**	**90**	**65**	**19**	**3**			**4**	**4**	**7**	**7**		**26**	**26**	**75**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

Campylobacter spp. include unidentified species, some of which may be intrinsically resistant to nalidixic acid.

Table 4. 16 Number of antimicrobial classes in resistance patterns of *Salmonella* from pigs, 2016

Serovar	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial												
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
Derby	36 (19.3)	12	8	14	2			16	4	1	1	1		14			1			23
Typhimurium	24 (12.8)	1	5	4	14			17	17					18	3		14			18
Infantis	22 (11.8)	19	2	1				2	1	1	1	1		1	1		1			2
Brandenburg	18 (9.6)	13	3	2				3						3	3					4
Schwarzengrund	13 (7.0)	12	1					1						1	1					
London	12 (6.4)	12																		
Ohio	8 (4.3)	5			1	2	1	3	2					3	2	2	3			3
4,[5],12:i:-	6 (3.2)	1	1		4			4	4					4						5
Livingstone	5 (2.7)		5					1												5
Agona	4 (2.1)	2	2																	2
Uganda	4 (2.1)	3		1				1						1						1
Less common serovars	35 (18.7)	21	2	8	3	1	3	12	5	2	2	2		10	3	1	5			11
Total	**187 (100)**	**101**	**29**	**30**	**24**	**3**	**4**	**60**	**33**	**4**	**4**	**4**		**55**	**13**	**3**	**24**			**74**

The disparity between the total number of isolates reported in the temporal figure (n = 188) and multiclass resistance table (n = 187) is due to missing serotyping information.

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

Serovars represented by less than 2% of isolates were classified as “Less common serovars”.

Table 4. 17 Number of antimicrobial classes in resistance patterns of *Escherichia coli* from pigs, 2016

Animal species	Number of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial											
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
Pigs	182	30	55	72	25			66	64	5	5	4		62	17	2	30		2	129

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

Table 4. 18 Number of antimicrobial classes in resistance patterns of *Campylobacter* from pigs, 2016

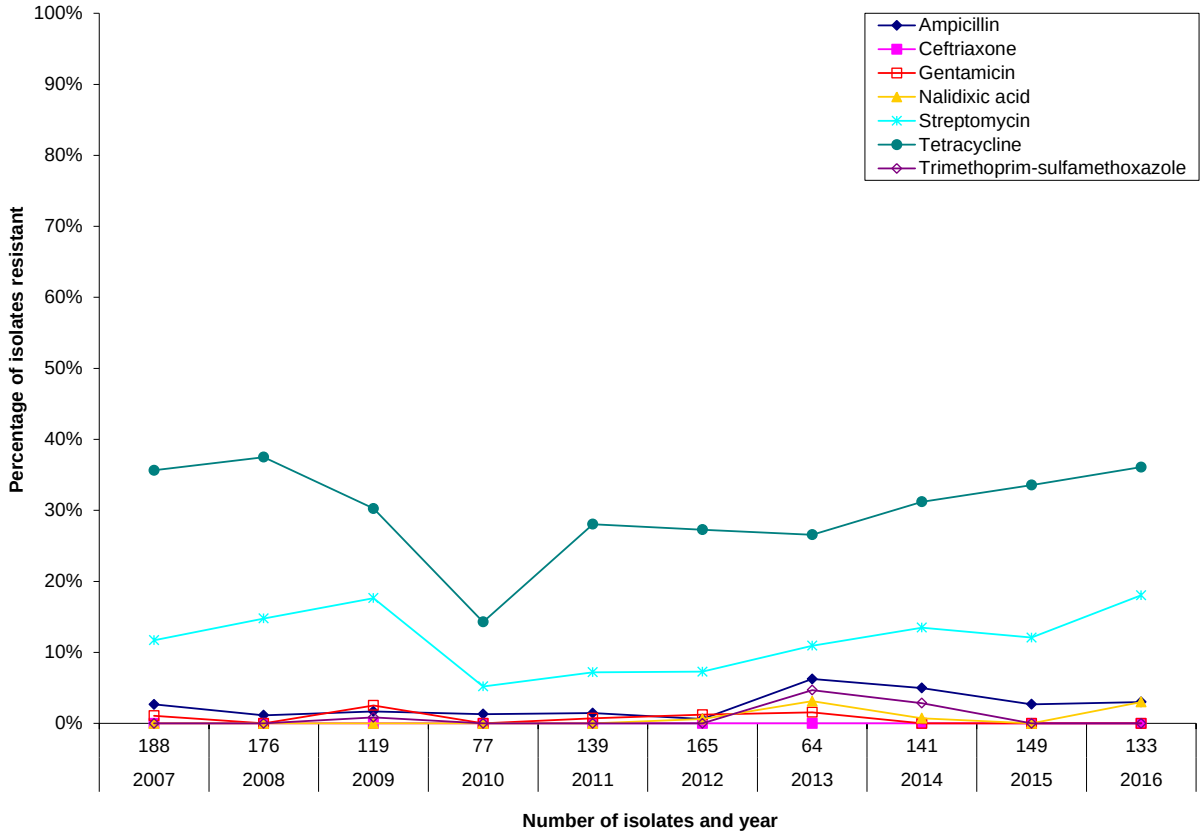
Species	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial							
							Aminoglycosides	Ketolides	Lincosamides	Macrolides		Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	TEL	CLI	AZM	ERY	FLR	CIP	NAL	TET
Campylobacter coli	264 (99.6)	40	79	66	79			103	111	120	120		35	35	205
Campylobacter spp.	1 (0.4)		1												1
Total	**265 (100)**	**40**	**80**	**66**	**79**			**103**	**111**	**120**	**120**		**35**	**35**	**206**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

Temporal antimicrobial resistance summary

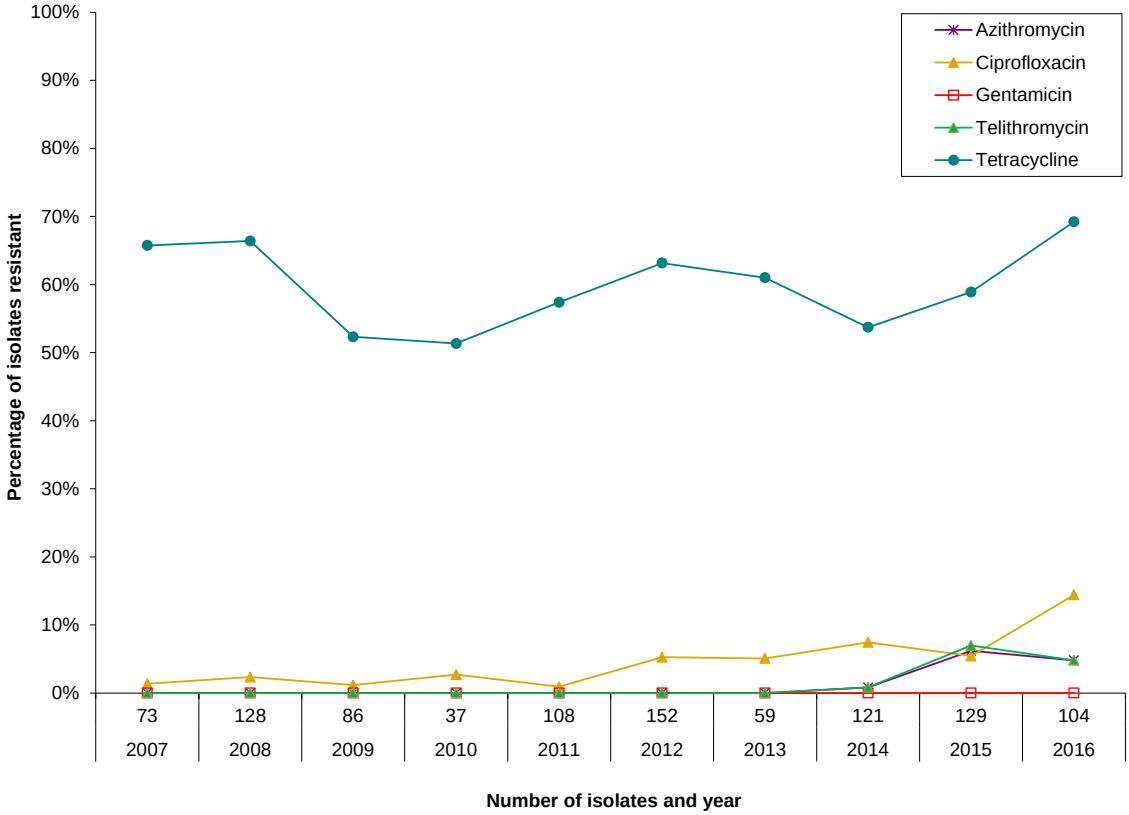
Figure 4. 19 Temporal variations in resistance of *Escherichia coli* isolates from beef cattle, 2007 to 2016



Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Number of isolates	188	176	119	77	139	165	64	141	149	133
Antimicrobial										
Ampicillin	**3%**	1%	2%	1%	1%	**1%**	6%	5%	**3%**	**3%**
Ceftriaxone	**0%**	0%	0%	0%	0%	**0%**	0%	0%	**0%**	**0%**
Gentamicin	**1%**	0%	3%	0%	1%	**1%**	2%	0%	**0%**	**0%**
Nalidixic acid	**0%**	0%	0%	0%	0%	**1%**	3%	1%	**0%**	**3%**
Streptomycin	**12%**	15%	18%	5%	7%	**7%**	11%	13%	**12%**	**18%**
Tetracycline	**36%**	38%	30%	14%	28%	**27%**	27%	31%	**34%**	**36%**
Trimethoprim-sulfamethoxazole	**0%**	0%	1%	0%	0%	**0%**	5%	3%	**0%**	**0%**

For the temporal analyses, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the previous 10 years, 5 years, and the preceding surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given antimicrobial.

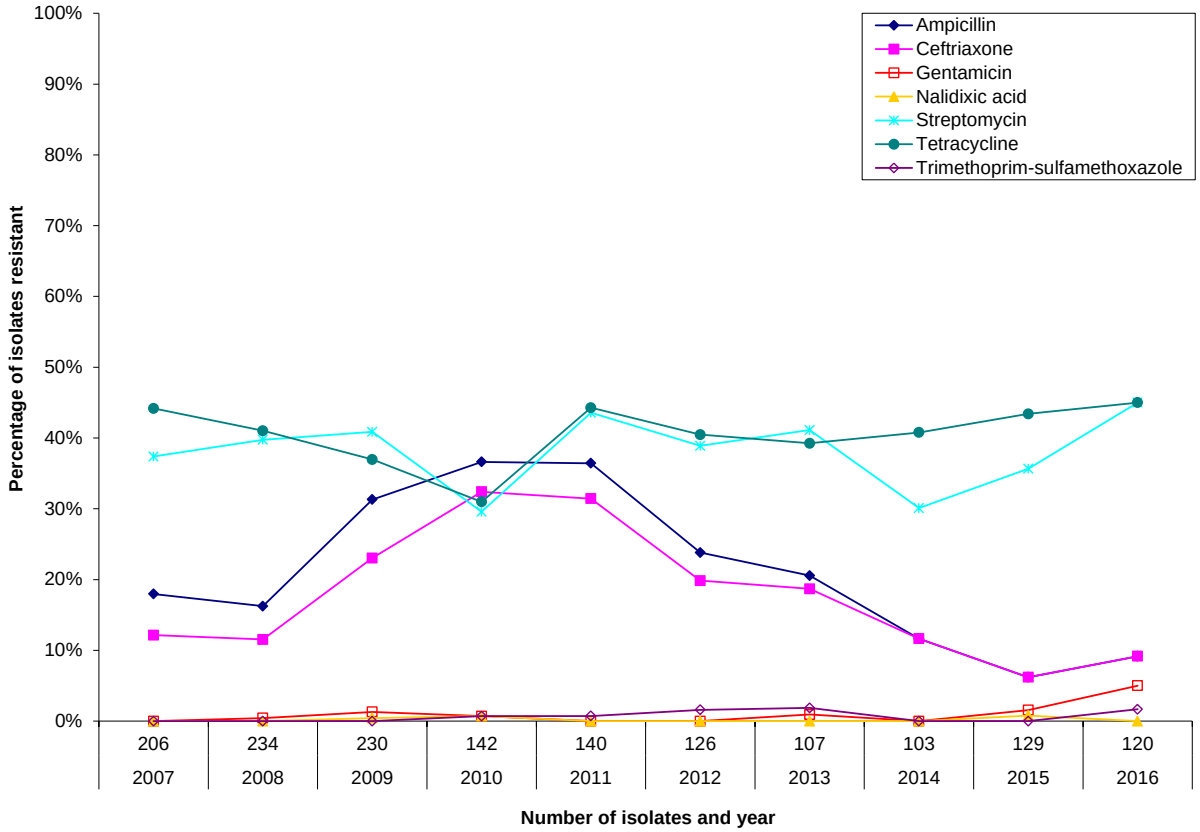
Figure 4. 20 Temporal variations in resistance of *Campylobacter* from beef cattle, 2007 to 2016



Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Number of isolates	73	128	86	37	108	152	59	121	129	104
Antimicrobial										
Azithromycin	**0%**	0%	0%	0%	0%	**0%**	0%	1%	**6%**	**5%**
Ciprofloxacin	**1%**	2%	1%	3%	1%	**5%**	5%	7%	**5%**	**14%**
Gentamicin	**0%**	0%	0%	0%	0%	**0%**	0%	0%	**0%**	**0%**
Telithromycin	**0%**	0%	0%	0%	0%	**0%**	0%	1%	**7%**	**5%**
Tetracycline	**66%**	66%	52%	51%	57%	**63%**	61%	54%	**59%**	**69%**

For the temporal analyses, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the previous 10 years, 5 years, and the preceding surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given antimicrobial.

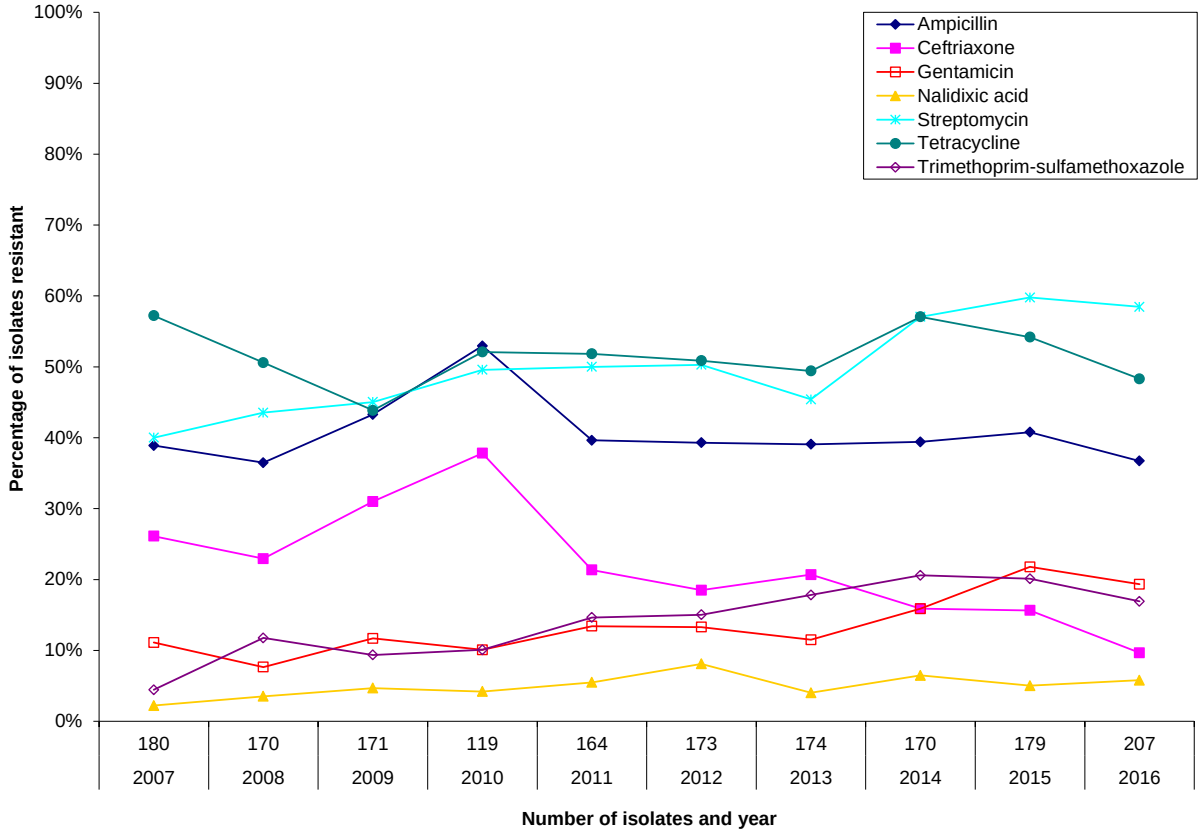
Figure 4. 21 Temporal variations in resistance of *Salmonella* isolates from chicken, 2007 to 2016



Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Number of isolates	206	234	230	142	140	126	107	103	129	120
Antimicrobial										
Ampicillin	**18%**	16%	31%	37%	36%	**24%**	21%	12%	**6%**	**9%**
Ceftriaxone	**12%**	12%	23%	32%	31%	**20%**	19%	12%	**6%**	**9%**
Gentamicin	**0%**	0%	1%	1%	0%	**0%**	1%	0%	**2%**	**5%**
Nalidixic acid	**0%**	0%	0%	1%	0%	**0%**	0%	0%	**1%**	**0%**
Streptomycin	**37%**	40%	41%	30%	44%	**39%**	41%	30%	**36%**	**45%**
Tetracycline	**44%**	41%	37%	31%	44%	**40%**	39%	41%	**43%**	**45%**
Trimethoprim-sulfamethoxazole	**0%**	0%	0%	1%	1%	**2%**	2%	0%	**0%**	**2%**

For the temporal analyses, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the previous 10 years, 5 years, and the preceding surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given antimicrobial.

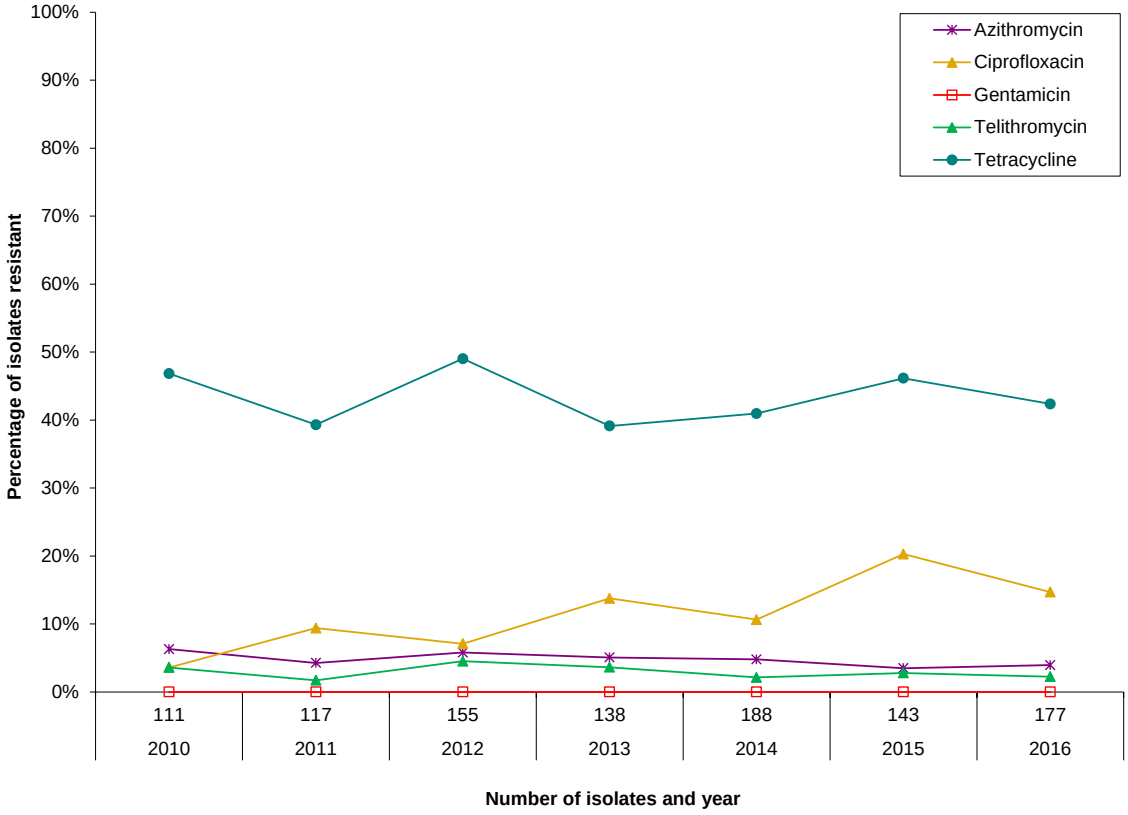
Figure 4. 22 Temporal variations in resistance of *Escherichia coli* isolates from chicken, 2007 to 2016



Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Number of isolates	180	170	171	119	164	173	174	170	179	207
Antimicrobial										
Ampicillin	**39%**	36%	43%	53%	40%	**39%**	39%	39%	**41%**	**37%**
Ceftriaxone	**26%**	23%	31%	38%	21%	**18%**	21%	16%	**16%**	**10%**
Gentamicin	**11%**	8%	12%	10%	13%	**13%**	11%	16%	**22%**	**19%**
Nalidixic acid	**2%**	4%	5%	4%	5%	**8%**	4%	6%	**5%**	**6%**
Streptomycin	**40%**	44%	45%	50%	50%	**50%**	45%	57%	**60%**	**58%**
Tetracycline	**57%**	51%	44%	52%	52%	**51%**	49%	57%	**54%**	**48%**
Trimethoprim-sulfamethoxazole	**4%**	12%	9%	10%	15%	**15%**	18%	21%	**20%**	**17%**

For the temporal analyses, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the previous 10 years, 5 years, and the preceding surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given antimicrobial.

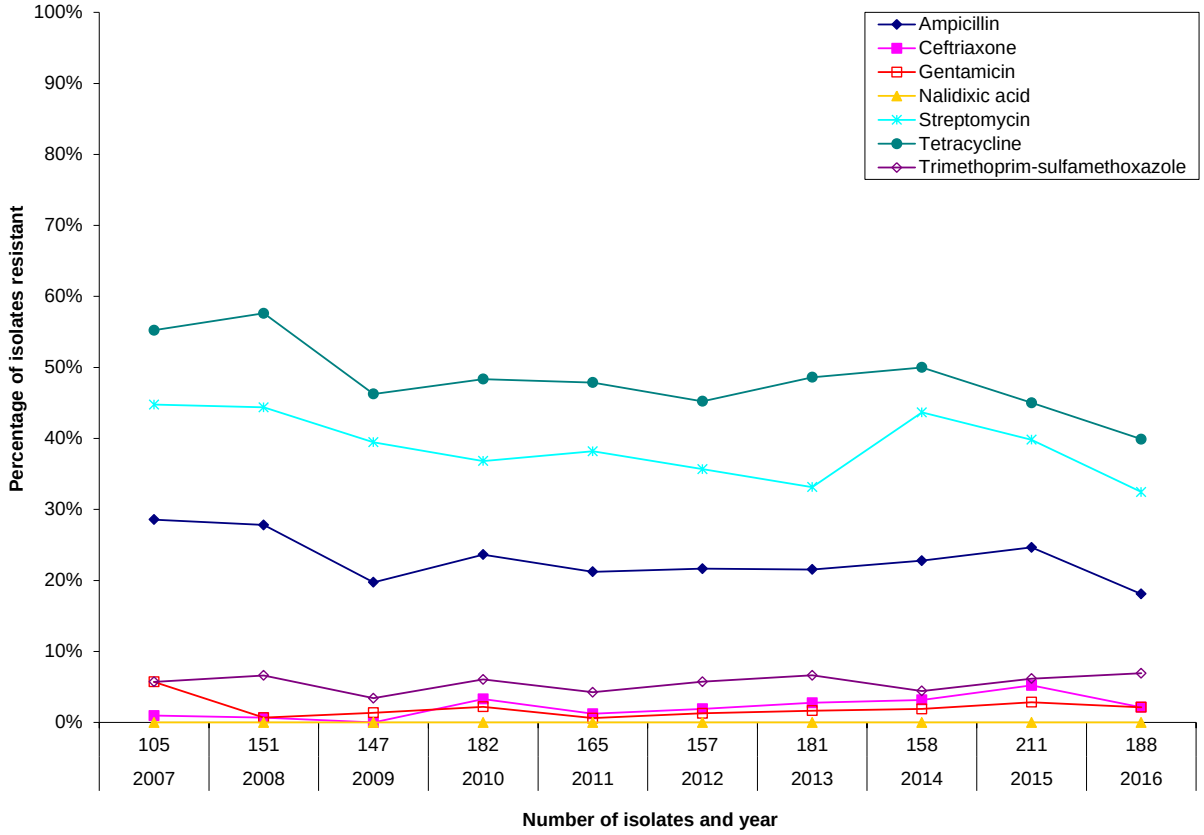
Figure 4. 23 Temporal variations in resistance of *Campylobacter* isolates from chickens, 2010 to 2016



Year	2010	2011	2012	2013	2014	2015	2016
Number of isolates	111	117	155	138	188	143	177
Antimicrobial							
Azithromycin	**6%**	4%	**6%**	5%	5%	**3%**	**4%**
Ciprofloxacin	**4%**	9%	**7%**	14%	11%	**20%**	**15%**
Gentamicin	**0%**	0%	**0%**	0%	0%	**0%**	**0%**
Telithromycin	**4%**	2%	**5%**	4%	2%	**3%**	**2%**
Tetracycline	**47%**	39%	**49%**	39%	41%	**46%**	**42%**

For the temporal analyses, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the first year of surveillance, 5 years, and the preceding surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given antimicrobial.

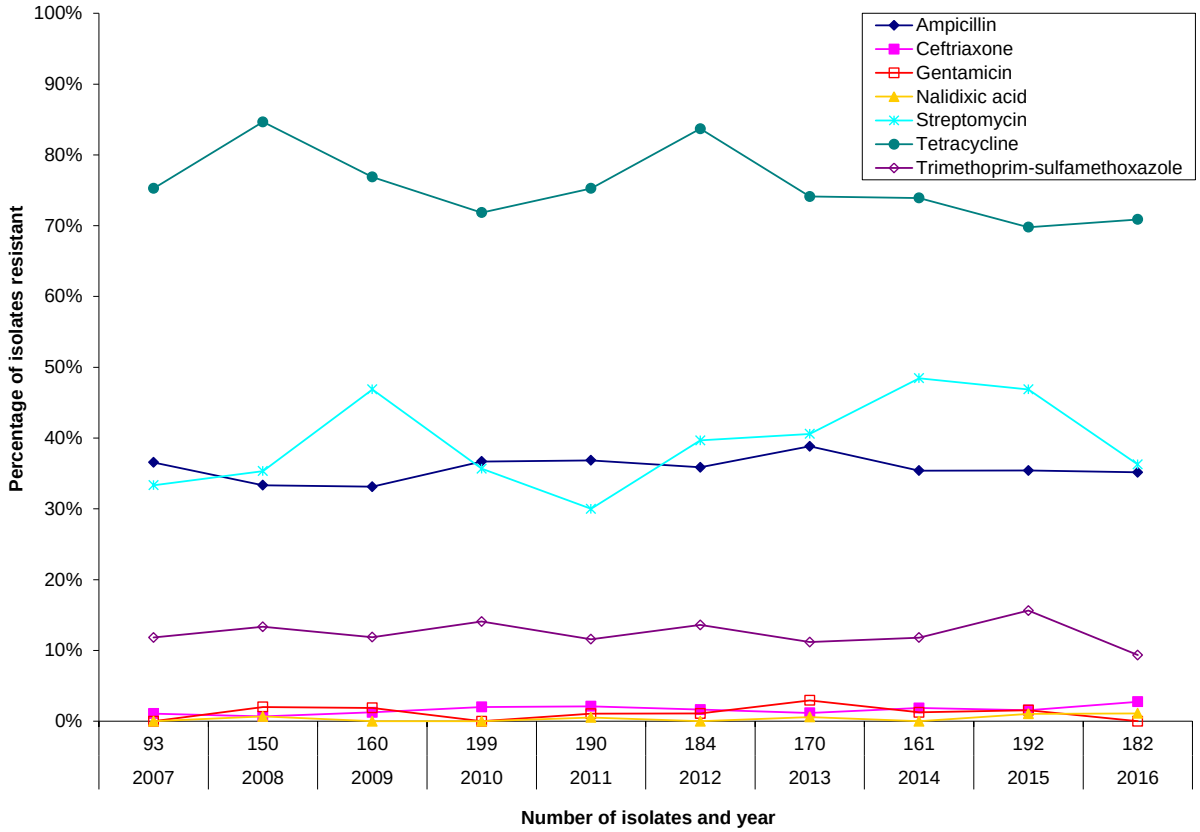
Figure 4. 24 Temporal variations in resistance of *Salmonella* isolates from pigs, 2007 to 2016



Year Number of isolates	2007 105	2008 151	2009 147	2010 182	2011 165	2012 157	2013 181	2014 158	2015 211	2016 188
Antimicrobial										
Ampicillin	**29%**	28%	20%	24%	21%	**22%**	22%	23%	**25%**	**18%**
Ceftriaxone	**1%**	1%	0%	3%	1%	**2%**	3%	3%	**5%**	**2%**
Gentamicin	**6%**	1%	1%	2%	1%	**1%**	2%	2%	**3%**	**2%**
Nalidixic acid	**0%**	0%	0%	0%	0%	**0%**	0%	0%	**0%**	**0%**
Streptomycin	**45%**	44%	39%	37%	38%	**36%**	33%	44%	**40%**	**32%**
Tetracycline	**55%**	58%	46%	48%	48%	**45%**	49%	50%	**45%**	**40%**
Trimethoprim-sulfamethoxazole	**6%**	7%	3%	6%	4%	**6%**	7%	4%	**6%**	**7%**

For the temporal analyses, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the previous 10 years, 5 years, and the preceding surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given antimicrobial.

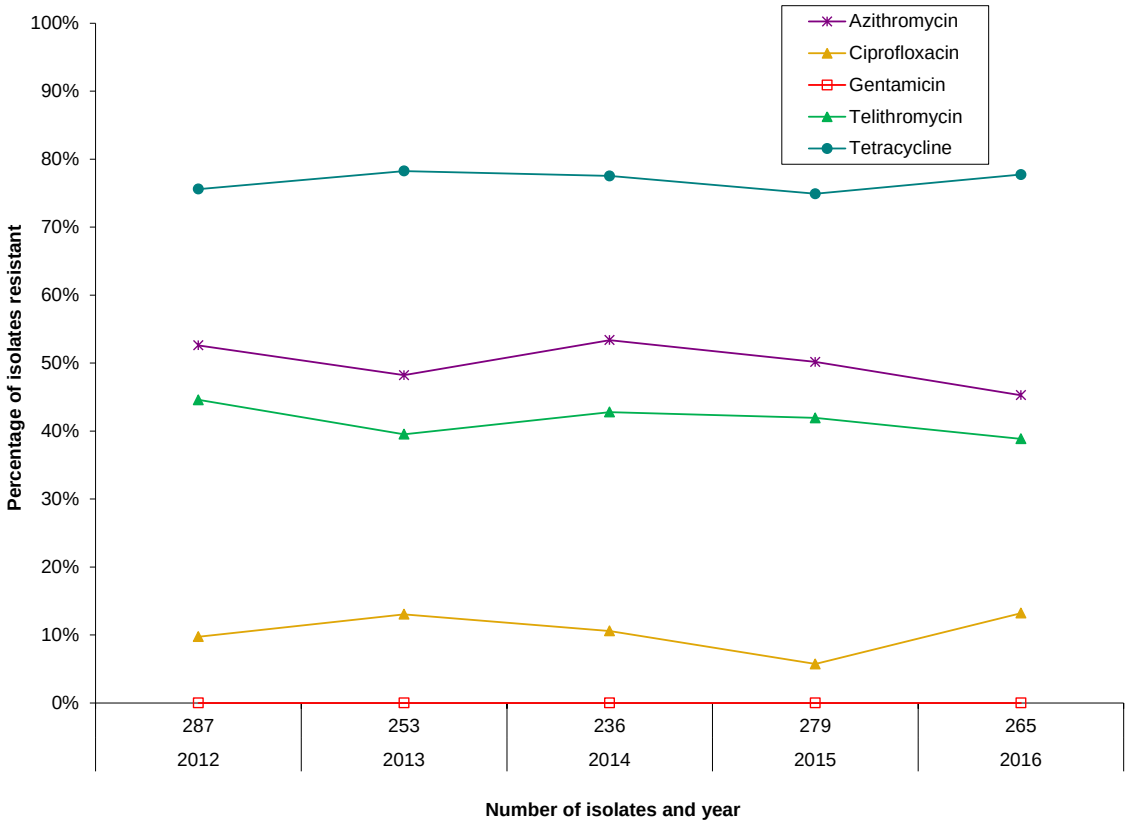
Figure 4. 25 Temporal variations in resistance of *Escherichia coli* isolates from pigs, 2007 to 2016



Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Number of isolates	93	150	160	199	190	184	170	161	192	182
Antimicrobial										
Ampicillin	**37%**	33%	33%	37%	37%	**36%**	39%	35%	**35%**	**35%**
Ceftriaxone	**1%**	1%	1%	2%	2%	**2%**	1%	2%	**2%**	**3%**
Gentamicin	**0%**	2%	2%	0%	1%	**1%**	3%	1%	**2%**	**0%**
Nalidixic acid	**0%**	1%	0%	0%	1%	**0%**	1%	0%	**1%**	**1%**
Streptomycin	**33%**	35%	47%	36%	30%	**40%**	41%	48%	**47%**	**36%**
Tetracycline	**75%**	85%	77%	72%	75%	**84%**	74%	74%	**70%**	**71%**
Trimethoprim-sulfamethoxazole	**12%**	13%	12%	14%	12%	**14%**	11%	12%	**16%**	**9%**

For the temporal analyses, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the previous 10 years, 5 years, and the preceding surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given antimicrobial.

Figure 4. 26 Temporal variations in resistance of *Campylobacter* isolates from pigs, 2012 to 2016



Year	2012	2013	2014	2015	2016
Number of isolates	287	253	236	279	265
Antimicrobial					
Azithromycin	**53%**	48%	53%	**50%**	**45%**
Ciprofloxacin	**10%**	13%	11%	**6%**	**13%**
Gentamicin	**0%**	0%	0%	**0%**	**0%**
Telithromycin	**45%**	40%	43%	**42%**	**39%**
Tetracycline	**76%**	78%	78%	**75%**	**78%**

For the temporal analyses, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the first year of surveillance and the preceding surveillance year (grey areas). The presence of blue areas indicates significant differences ($P \leq 0.05$) for a given antimicrobial.

Recovery results

Table 4. 19 Abattoir Surveillance recovery rates, 2002 to 2016

Animal species	Year	Percentage (%) of isolates recovered and number of isolates recovered / number of samples submitted							
		Escherichia coli		*Salmonella*		*Campylobacter*		*Enterococcus*	
Beef cattle	2002	**97%**	76/78	**1%**	3/78				
	2003	**97%**	155/159	**< 1 %**	1/114				
	2004	**98%**	167/170						
	2005	**97%**	122/126			**66%**	23/35		
	2006	**100%**	150/150			**36%**	31/87		
	2007	**99%**	188/190			**39%**	75/190		
	2008	**97%**	176/182			**71%**[a]	129/182		
	2009	**94%**	119/126			**68%**	86/126		
	2010	**97%**[b]	77/79			**53%**[b]	37/70		
	2011	**99%**	139/141			**77%**	108/141		
	2012	**99%**	165/166			**92%**	152/166		
	2013	**100%**[b]	59/59			**92%**[b]	54/59		
	2014	**99%**	141/142			**87%**	123/142		
	2015	**98%**	149/152			**85%**	129/152		
	2016	**98%**	133/136			**76%**	104/136		
Chickens	2002	**100%**	40/40	**13%**	25/195				
	2003	**97%**	150/153	**16%**	126/803				
	2004	**99%**	130/131	**16%**	142/893				
	2005	**99%**	218/220	**18%**	200/1,103				
	2006	**100%**	166/166	**23%**	187/824				
	2007	**99%**	180/181	**25%**	204/808				
	2008	**99%**	170/171	**28%**	234/851				
	2009	**100%**	171/171	**27%**	230/851				
	2010	**99%**	119/120	**24%**	142/599	**19%**	111/599		
	2011	**99%**	164/166	**20%**	140/701	**17%**	117/696		
	2012	**100%**	173/173	**18%**[c]	126/684	**23%**	155/685		
	2013	**99%**	171/172	**16%**	105/672	**21%**	137/662		
	2014	**100%**	170/170	**15%**	103/684	**27%**	187/683		
	2015	**99%**	179/181	**18%**	128/708	**20%**	143/709		
	2016	**99%**	207/208	**14%**	120/840	**21%**	177/842		

See corresponding footnotes at the end of the table.

Table 4. 19 Abattoir Surveillance recovery rates, 2002 to 2016 (continued)

Animal species	Year	Percentage (%) of isolates recovered and number of isolates recovered / number of samples submitted						
		Escherichia coli		*Salmonella*		*Campylobacter*		*Enterococcus*
Pigs	2002	**97%**	38/39	**27%**	103/385			
	2003	**98%**	153/155	**28%**	395/1,393			
	2004	**99%**	142/143	**38%**	270/703			
	2005	**99%**	163/164	**42%**	212/486			
	2006	**98%**	115/117	**40%**	145/359			
	2007	**98%**	93/95	**36%**	105/296			
	2008	**100%**	150/150	**44%**	151/340			
	2009	**98%**	160/163	**45%**	147/327			
	2010	**98%**	199/203	**44%**	182/410			
	2011	**99%**	190/191	**43%**	165/382			
	2012	**100%**	184/184	**42%**	157/370	**78%**	289/370	
	2013	**99%**	166/168	**52%**	171/330	**76%**	237/314	
	2014	**99%**	161/162	**49%**	158/325	**73%**	237/325	
	2015	**98%**	192/195	**55%**	211/385	**72%**	279/385	
	2016	**99%**	182/184	**51%**	188/367	**72%**	265/366	

Grey-shaded areas indicate either: a) isolates recovered from sampling activities outside the scope of CIPARS routine (or "core") surveillance in the specified year (i.e. grey-shaded areas with data) or b) discontinuation or no surveillance activity (i.e. grey-shaded areas with no data).

[a] Implementation of a new *Campylobacter* recovery method in 2008 in abattoir beef cattle isolates.

[b] In 2010 and 2013, the number of samples received from abattoir beef cattle was much lower than anticipated due to a drop in submissions related to unavoidable operational issues at 2 major participating abattoirs.

[c] Decreased prevalence in chickens and one non-compliant plant (lack of sampling) resulted in a shortfall of *Salmonella* isolates from chickens.

Farm Surveillance

Key findings

A summary of Farm Surveillance recovery rates for broiler chickens, feedlot beef, grower-finisher pigs, and turkeys are presented in Table 4. 32, Table 4. 33, Table 4. 34, and Table 4. 35.

Feedlot beef[69,70]

This is the first year reporting feedlot beef data. All samples were collected from the FoodNet Canada Alberta site. The data represent a partial sampling year with only 13 feedlots being enrolled and sampled. The goal in future years is to enroll approximately 30 feedlots

Salmonella (n = 3)

Three isolates were obtained from composite feedlot beef fecal samples; 2 Enteritidis and 1 Infantis. Two of the 3 isolates were obtained from sampling one feedlot. All isolates were susceptible to all antimicrobials tested.

Escherichia coli (n = 78)

No isolates were resistant to Category I antimicrobials and no isolate was resistant to 6 or more classes of antimicrobials (Table 4. 20). The majority of resistance detected was to tetracycline with 51% (40/78) of the isolates classified as resistant (Table 4. 20 and Figure 4. 27). Three (4%) isolates were resistant to nalidixic acid, however, no isolates were resistant to ciprofloxacin (Table 4. 20 and Figure 4. 27).

Campylobacter (n = 56)

Ninety-one percent (51/56) of *Campylobacter* isolates recovered from feedlot beef cattle feces were resistant to tetracycline (Table 4. 21). Of these isolates 27 (53%, 27/51) were *C. coli*, 23 (45%, 23/51) *C. jejuni* and 1 (2%, 1/51) *Campylobacter* spp. (Table 4. 21). The only other resistances detected were to ciprofloxacin (9%, 5/56) and nalidixic acid (11%, 6/56) (Figure 4. 28). The majority of these isolates were *C. jejuni* and *Campylobacter* spp. (Table 4. 21). The CIP-NAL-TET pattern of resistance was found in 4 isolates from 3 different feedlots. No isolates were resistant to more than 2 antimicrobial classes.

[69] Thirteen feedlots in the FoodNet Canada Alberta site were sampled in 2016.

[70] Proportion of resistant isolates presented in the key findings section may slightly differ from those presented in the figures/tables (percentages adjusted for clustering to account for multiple samples per flock). Please refer to both the tables depicting the number of antimicrobial classes and the temporal figures and supporting tables.

Broiler chickens[71,72]

Salmonella (n = 361)

Placement (n = 35)

When data from all provinces/regions were combined as a whole, the top 3 *Salmonella* serovars were Enteritidis (19/35, 54%), Kentucky (10/35, 29%), and Heidelberg (4/35, 11%). Provincial differences in serovar distribution were noted with Enteritidis being the only serovar isolated in British Columbia (100%, 10/10) (Table 4. 22). Heidelberg (n = 2) was the only serovar in Ontario and Kentucky was the most common (8/15, 53%) in Québec (Table 4. 22). Enteritidis was the top serovar detected from chick pads (61%, 19/31 chick pad isolates) and there were 2 Heidelberg and 1 Kentucky isolate detected from the environment. All Enteritidis isolates were susceptible to all antimicrobials tested (Table 4. 22).

No ciprofloxacin or nalidixic acid resistance was observed in any serovar (Table 4. 22).

One chick placement isolate (Alachua, isolated from the Prairies) was resistant to ceftriaxone and all other β-lactam antimicrobials except meropenem (Table 4. 22). This isolate was also resistant to 5 classes of antimicrobials.

Resistance to meropenem was not detected in any of the placement isolates.

Pre-harvest (n = 250)

When data from all provinces/regions were combined, the top 3 *Salmonella* serovars were Kentucky (37%, 92/250) Enteritidis (16%, 40/250), and Heidelberg (11%, 28/250) (Table 4. 23). Regional differences in serovar distribution were observed with Kentucky being the most common serovar in British Columbia (40%, 29/73), Heidelberg in the Prairies (24%, 16/66), Mbandaka in Ontario (25%, 12/49), and Kentucky (74%, 46/62) in Québec (Table 4. 23).

None of the Enteritidis isolates were resistant to any of the antimicrobials tested (Table 4. 23).

When data from all provinces/regions were combined as a whole, ceftriaxone resistance was 7% (Table 4. 23) and significantly lower than the previous year (13%). Regionally, ceftriaxone resistance significantly decreased in the Prairies between 2013 (32%) and 2016 (2%). Similarly, resistance also decreased significantly in Ontario over the same timeframe (43% in 2013 and 2% in 2016) (Figure 4. 31).

Resistance to meropenem was not detected in any of the pre-harvest isolates.

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[71] One hundred and thirty-six flocks from 136 different farm premises across 4 poultry producing regions or 5 provinces (British Columbia, Prairies [Alberta and Saskatchewan], Ontario, and Québec) were enrolled in 2016, 57 flocks (42%) were also sampled at chick placement.

[72] Proportion of resistant isolates presented in the key findings section may slightly differ from those presented in the figures and tables (percentages adjusted for clustering to account for multiple samples per flock). Please refer to both the tables depicting the number of antimicrobial classes and the temporal figures and supporting tables.

Escherichia coli (n = 763)[73]

Placement (n = 220)

Two isolates (1 from chick pads and 1 from the environment) from British Columbia were resistant to ciprofloxacin and 12 isolates were resistant to nalidixic acid, 10 from British Columbia, and 2 from the Prairies (Table 4. 24). One isolate from British Columbia was resistant to 6 classes of antimicrobials.

Overall, the proportion of isolates resistant to ceftriaxone significantly decreased between 2016 (18%) and 2013 (39%). Regionally, resistance to ceftriaxone significantly decreased between 2013 and 2016 in British Columbia (67% to 18%) and the Prairies (68% to 21%) and significantly decreased between 2015 and 2016 in Québec (42% to 11%) (Figure 4. 30).

Resistance to gentamicin decreased overall but not significantly (39% in 2015, 28% in 2016). Regionally, gentamicin resistance significantly decreased in British Columbia (70% in 2015 and 33% in 2016) and the Prairies (39% in 2013 and 14% in 2016) (Figure 4. 30). Resistance to gentamicin remained relatively high in placement isolates from Québec (39%) compared to other regions (Figure 4. 30).The resistant isolates were recovered from both chick pads (31%, 48/153) and environmental samples (21%, 14/67). These results are similar to the previous year, which is suggestive that contamination and antimicrobial use (please see the antimicrobial use hatchery section above) upstream of the production pyramid contribute to the self-perpetuating nature of gentamicin resistance in broilers.

Resistance to meropenem was not detected in any of the placement isolates.

Pre-harvest (n = 543)

Twenty-five isolates (5%, 25/543), recovered across all provinces/regions were resistant to nalidixic acid (Table 4. 25). One isolate was resistant to 6 classes of antimicrobials.

Overall, resistance to ceftriaxone significantly decreased between 2013 and 2016 (32% to 9%). Regionally, decreased resistance was noted in all regions (Figure 4. 32).

Resistance to gentamicin significantly increased overall between 2013 and 2016 (13% to 21%). Regionally, it significantly increased in Ontario between 2013 and 2016 (10% to 25%) and between 2015 and 2016 (13% to 25%); it remained relatively stable in the Prairies and Québec (Figure 4. 32).

Resistance to meropenem was not detected in any of the pre-harvest isolates.

Campylobacter (n = 93)

Placement (n = 0)

Campylobacter was not isolated from the chick placement samples because of well documented/reported challenges in recovering this organism from chicks or newly cleaned barn environments.

[73] Consisted of normal avian gut, environmental commensals, and avian pathogenic *E. coli* responsible for yolksacculitis and septicemic diseases. As in other components, isolates were not further characterized.

Pre-harvest (n = 93)

Resistance to nalidixic acid and ciprofloxacin slightly decreased overall between 2015 and 2016 (16%, to 13%). The resistant isolates were collected from farms in British Columbia (29%, 9/31) and the Prairies (14%, 4/28) (Table 4. 26). There were no ciprofloxacin resistant isolates detected from Ontario and Québec (Table 4. 26). Unlike in the previous year, there was no telithromycin resistance detected in any of the isolates.

Grower-finisher pigs

Salmonella (n = 110)[74,75]

The most common serovars detected were Derby (28%, 31/110), Typhimurium (21%, 23/110) and Brandenburg (13%, 14/110); which collectively made up almost 62% of all reported serovars (Table 4. 27). Depending on the region the most prevalent serovars detected varied slightly, however, Derby and Typhimurium were always in the top 3. Only one isolate, an Ohio, from the province of Québec had resistance to more than 5 antimicrobial classes; ACSSuT-AZM-GEN-SXT (7 classes).

On a national basis *Salmonella* resistance levels were relatively stable. There was a statistically significant decrease in ampicillin resistance from 31% in 2015 to 23% in 2016 (data not shown). Tetracycline resistance was also significantly lower in 2016 (51%) than in 2015 (60%) or than in 2012 (62%) (data not shown).

Regionally, there was more variation in the resistance data than on a national level (Figure 4. 34). In the Prairies, although not statistically significant, there was an increase in ampicillin resistance from 5% in 2015 to 23% in 2016. However, when looking at the historical values for this region the 2016 resistance prevalence was more in keeping with what has been previously observed. In Ontario, ampicillin resistance significantly decreased from 52% in 2015 to 11% in 2016. Ampicillin resistance has also been trending downward in the province of Québec since 2014, although no significant differences were detected.

Resistance to streptomcyin in Ontario has continued to decrease over the last 5 years (Figure 4. 34). There was a significant decrease in streptomycin resistance from 63% in 2012 to 39% in 2016. Also, in Ontario resistance to tetracycline has continued to decrease from a peak of 91% in 2014 to 54% in 2016.

In Québec resistance to trimethoprim-sulfamethoxazole was statistically significantly higher in 2016 (29%) than 2012 (5%).

Escherichia coli (n = 544)

Similar to the *Salmonella* data there were very few *E. coli* isolates with resistance to more than 5 classes of antimicrobials (Table 4. 28). Two isolates from the province of Québec had resistance to 6 classes of antimicrobials; ACSSuT-AZM-SXT (Table 4. 28). There was 1 *E. coli* isolate from the Prairies that was resistant to 9 antimicrobials and 5 classes with an ACSSuT-AMC-FOX-CRO-SXT pattern. Additionally, 1 isolate from the Prairies and 2 from Ontario were

[74] Ninety-one operations in the 5 major pork producing provinces (Alberta, Saskatchewan, Manitoba, Ontario and Québec) were sampled in 2016.

[75] Proportion of resistant isolates presented in the key findings section may slightly differ from those presented in the figures/tables (percentages adjusted for clustering to account for multiple samples per flock). Please refer to both the tables depicting the number of antimicrobial classes and the temporal figures and supporting tables.

resistant to 8 antimicrobials and 4 antimicrobial classes. All of these isolates had the same pattern of AMC-AMP-FOX-CR0-STR-SSS-SXT-TET.

Nationally, *E. coli* resistance was relatively stable (data not shown). There was more variation in antimicrobial resistance at a regional level than a national level (Figure 4. 35). Despite there being some variation, there were no significant changes detected in resistance for the Prairies and Ontario. However, although not significant, ceftriaxone resistance did appear to be trending downward in Ontario. On the other hand, in Québec, ceftriaxone resistance has statistically significantly increased from 1% in 2012 to 4% in 2016. The only other notable finding was a significant decrease in tetracycline resistance from 87% in 2012 to 79% in 2016 in the province of Québec.

Turkeys

Salmonella (n = 146)

When data from all provinces were combined, the top 3 *Salmonella* serovars were Hadar (23%, 34/146), Agona (18%, 26/146), and Muenchen (16%, 23/146) (Table 4. 29). Regional differences in serovar distribution were observed with Hadar being the most common serovar in British Columbia (60%, 30/50), Muenchen in Ontario (31%,22/70) and Agona in Québec (27%, 7/26) (Table 4. 29). Heidelberg was isolated in both Ontario (1 isolate) and Québec (2 isolates).

Overall, resistance to ceftriaxone was 3% (5/146); the resistant isolates were Heidelberg (1 isolate), Indiana (3 isolates) and Bredeney (1 isolate), all originated from Ontario farms (Table 4. 29).

Thirty-two percent (47/146) of the isolates were resistant to gentamicin; 81% (58/72) of the flocks administered this antimicrobial at the hatchery to poults (please see Chapter 3: Antimicrobial use in animals). Resistance was seen in multiple serovars (Table 4. 29).

Resistance to meropenem was not detected in any of the isolates.

Escherichia coli (n = 277)

Of the 277 isolates, only 2 isolates (less than 1%), were resistant to ceftriaxone (Table 4. 30). No isolate was resistant to 6 or more classes of antimicrobials.

One isolate (less than 1%, 1/277), recovered from a sample in Ontario was resistant to ciprofloxacin. Two isolates from British Columbia and 1 isolate from Ontario were resistant to nalidixic acid (1%, 3/27) (Table 4. 30).

Twenty percent (56/277) of the isolates were resistant to gentamicin (Table 4. 30).

Resistance to meropenem was not detected in any of the isolates.

Campylobacter (n = 171)

Twenty-three percent (40/171) of the isolates were resistant to nalidixic acid and ciprofloxacin; resistance was observed in both *C. coli* (30%, 19/64 of *C. coli* isolates) and *C. jejuni* (20%, 21/107 of *C. jejuni* isolates). The resistant isolates were largely from flocks in British Columbia (47%, 37/79). There were 3 resistant isolates recovered from Ontario flocks (5%, 3/65) and none from Québec flocks (Table 4. 31). There were 2 isolates from Ontario (3%, 1/65) that were resistant to azithromycin.

Multiclass resistance

Table 4. 20 Number of antimicrobial classes in resistance patterns of *Escherichia coli* from feedlot beef, 2016

Species	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial											
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
Feedlot beef	78 (100)	38	21	16	3			16	2					11			3		3	40

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

Table 4. 21 Number of antimicrobial classes in resistance patterns of *Campylobacter* from feedlot beef, 2016

Species	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial							
							Aminoglycosides	Ketolides	Lincosamides	Macrolides		Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	TEL	CLI	AZM	ERY	FLR	CIP	NAL	TET
Campylobacter coli	27 (48.2)		27												27
Campylobacter jejuni	27 (48.2)	4	19	4									4	4	23
Campylobacter spp.	2 (3.6)		1	1									1	2	1
Total	**56 (100)**	**4**	**47**	**5**									**5**	**6**	**51**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

Campylobacter spp. include unidentified species, some of which may be intrinsically resistant to nalidixic acid.

Table 4. 22 Number of antimicrobial classes in resistance patterns of *Salmonella* from chicks and barn environment at placement, 2016

Province or region/serovar	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial											
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
British Columbia																				
Enteritidis	10 (100)	10																		
Total	**10 (100)**	**10**																		
Prairies																				
Enteritidis	3 (37.5)	3																		
Heidelberg	2 (25.0)	2																		
Kentucky	2 (25.0)			2				2												2
Alachua	1 (12.5)				1		1	1	1	1	1	1		1			1			1
Total	**8 (100)**	**5**		**2**	**1**		**1**	**3**	**1**	**1**	**1**	**1**		**1**			**1**			**3**
Ontario																				
Heidelberg	2 (100)	2																		
Total	**2 (100)**	**2**																		
Québec																				
Kentucky	8 (53.3)			8			1	8						1						8
Enteritidis	6 (40.0)	6																		
Ohio	1 (6.7)	1																		
Total	**15 (100)**	**7**		**8**			**1**	**8**						**1**						**8**
National																				
Enteritidis	19 (54.3)	19																		
Kentucky	10 (28.6)			10			1	10						1						10
Heidelberg	4 (11.4)	4																		
Alachua	1 (2.9)				1		1	1	1	1	1	1		1			1			1
Ohio	1 (2.9)	1																		
Total	**35 (100)**	**24**		**10**	**1**		**2**	**11**	**1**	**1**	**1**	**1**		**2**			**1**			**11**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

Serovars represented by less than 2% of isolates were classified as “Less common serovars”

The Prairies region includes Alberta and Saskatchewan.

Table 4. 23 Number of antimicrobial classes in resistance patterns of *Salmonella* from chickens pre-harvest, 2016

Province or region / serovar	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial											
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
British Columbia																				
Kentucky	29 (39.7)			29				29	9	9	9	9								29
Enteritidis	23 (31.5)	23																		
Cubana	5 (6.9)	5																		
Liverpool	5 (6.9)	2		3			1	3						3						3
Heidelberg	4 (5.5)	4																		
Johannesburg	4 (5.5)		4																	4
Typhimurium	2 (2.7)	2																		
Senftenberg	1 (1.4)	1																		
Total	**73 (100)**	**37**	**4**	**32**			**1**	**32**	**9**	**9**	**9**	**9**		**3**						**36**
Prairies																				
Heidelberg	16 (24.2)	11	5						5	1	1	1								
Enteritidis	11 (16.7)	11																		
Infantis	9 (13.6)	8	1											1	1					
Kentucky	9 (13.6)			9				9												9
Senftenberg	5 (7.6)	5																		
Agona	3 (4.6)			3			3	3						3						3
Schwarzengrund	3 (4.6)	3																		
Mbandaka	2 (3.0)	2																		
Typhimurium	2 (3.0)	2																		
Less common serovars	6 (9.1)	2		3	1		1	4	1					3						4
Total	**66 (100)**	**44**	**6**	**15**	**1**		**4**	**16**	**6**	**1**	**1**	**1**		**7**	**1**					**16**
Ontario																				
Mbandaka	12 (24.5)	12																		
Heidelberg	8 (16.3)	8																		
Kentucky	8 (16.3)			8				8												8
Braenderup	5 (10.2)	5																		
Infantis	5 (10.2)	4	1						1	1	1	1								
Enteritidis	4 (8.2)	4																		
Typhimurium	3 (6.1)			3										3						3
Liverpool	2 (4.1)	2																		
Livingstone	2 (4.1)		2																	2
Total	**49 (100)**	**35**	**3**	**11**				**8**	**1**	**1**	**1**	**1**		**3**						**13**
Québec																				
Kentucky	46 (74.2)	1		45				45	7	7	7	7								45
Enteritidis	2 (3.2)	2																		
Rough:i:z6	2 (3.2)			2				2												2
Litchfield	2 (3.2)			2			2	2						2						
Manhattan	2 (3.2)			2				2						2						2
Senftenberg	2 (3.2)	2																		
Tennessee	2 (3.2)			2				2						2	2					2
Less common serovars	4 (6.5)	1	1	2			1	2						2	1					1
Total	**62 (100)**	**6**	**1**	**55**			**3**	**55**	**7**	**7**	**7**	**7**		**8**	**3**					**52**
National																				
Kentucky	92 (36.8)	1		91				91	16	16	16	16								91
Enteritidis	40 (16.0)	40																		
Heidelberg	28 (11.2)	23	5						5	1	1	1								
Infantis	14 (5.6)	12	2						1	1	1	1		1	1					
Mbandaka	14 (5.6)	14																		
Senftenberg	8 (3.2)	8																		
Liverpool	7 (2.8)	4		3			1	3						3						3
Typhimurium	7 (2.8)	4		3										3						3
Braenderup	5 (2.0)	5																		
Cubana	5 (2.0)	5																		
Less common serovars	30 (12.0)	6	7	16	1		7	17	1					14	3					20
Total	**250 (100)**	**122**	**14**	**113**	**1**		**8**	**111**	**23**	**18**	**18**	**18**		**21**	**4**					**117**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

Serovars represented by less than 2% of isolates were classified as “Less common serovars”.

The Prairies region includes Alberta and Saskatchewan.

Table 4. 24 Number of antimicrobial classes in resistance patterns of *Escherichia coli* from chicks and barn environment at placement, 2016

Sample type / province or region	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial											
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
Chick pads																				
British Columbia	42 (27.5)	7	5	16	13	1	16	23	24	6	7	6		21	2		1	1	7	26
Prairies	30 (19.6)	11	8	7	4		4	5	13	8	8	8		5	1		2		2	16
Ontario	45 (29.4)	11	9	21	4		12	17	21	9	9	9		12	1					25
Québec	36 (23.5)	8	2	21	5		16	24	12	4	4	4		19	3		3			24
National	**153 (100)**	**37**	**24**	**65**	**26**	**1**	**48**	**69**	**70**	**27**	**28**	**27**		**57**	**7**		**6**	**1**	**9**	**91**
Environment																				
British Columbia	16 (23.9)	4	2	5	5		4	6	8	2	3	2		6	2			1	3	9
Prairies	10 (14.9)	4	1	5			2	2	2					2						4
Ontario	25 (37.3)	8	8	4	5		4	6	10	5	5	5		7	4		2			11
Québec	16 (23.9)	3	2	7	4		4	11	9	1	1	1		9	4		3			5
National	**67 (100)**	**19**	**13**	**21**	**14**		**14**	**25**	**29**	**8**	**9**	**8**		**24**	**10**		**5**	**1**	**3**	**29**
Placement																				
British Columbia	58 (26.4)	11	7	21	18	1	20	29	32	8	10	8		27	4		1	2	10	35
Prairies	40 (18.2)	15	9	12	4		6	7	15	8	8	8		7	1		2		2	20
Ontario	70 (31.8)	19	17	25	9		16	23	31	14	14	14		19	5		2			36
Québec	52 (23.6)	11	4	28	9		20	35	21	5	5	5		28	7		6			29
National	**220 (100)**	**56**	**37**	**86**	**40**	**1**	**62**	**94**	**99**	**35**	**37**	**35**		**81**	**17**		**11**	**2**	**12**	**120**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

The Prairies region includes Alberta and Saskatchewan.

Table 4. 25 Number of antimicrobial classes in resistance patterns of *Escherichia coli* from chickens at pre-harvest, 2016

Province or region	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial											
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
British Columbia	128 (23.6)	30	27	44	27		19	47	70	27	27	29		47	13		7		13	51
Prairies	152 (28.0)	43	28	64	16	1	31	75	52	11	11	11		43	9		8		5	82
Ontario	159 (29.3)	45	26	66	22		39	71	50	9	6	9		62	33		11		5	71
Québec	104 (19.2)	14	11	54	25		25	68	43	4	4	4		66	30		15		2	58
National	**543 (100)**	**132**	**92**	**228**	**90**	**1**	**114**	**261**	**215**	**51**	**48**	**53**		**218**	**85**		**41**		**25**	**262**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

The Prairies region includes Alberta and Saskatchewan.

Table 4. 26 Number of antimicrobial classes in resistance patterns of *Campylobacter* from chickens at pre-harvest, 2016

Province or region / species	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial							
							Aminoglycosides	Ketolides	Lincosamides	Macrolides		Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	TEL	CLI	AZM	ERY	FLR	CIP	NAL	TET
British Columbia															
Campylobacter jejuni	27 (87.1)	16	7	4									9	9	6
Campylobacter coli	4 (12.9)	4													
Total	**31 (100)**	**20**	**7**	**4**									**9**	**9**	**6**
Prairies															
Campylobacter jejuni	16 (57.1)	15	1												1
Campylobacter coli	12 (42.9)	8	4										4	3	
Total	**28 (100)**	**23**	**5**										**4**	**3**	**1**
Ontario															
Campylobacter jejuni	26 (100)	18	8												8
Total	**26 (100)**	**18**	**8**												**8**
Québec															
Campylobacter jejuni	8 (100)	4	4												4
Total	**8 (100)**	**4**	**4**												**4**
National															
Campylobacter jejuni	77 (82.8)	53	20	4									9	9	19
Campylobacter coli	16 (17.2)	12	4										4	3	
Total	**93 (100)**	**65**	**24**	**4**									**13**	**12**	**19**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

The Prairies region includes Alberta and Saskatchewan.

Table 4. 27 Number of antimicrobial classes in resistance patterns of *Salmonella* from pigs, 2016

Province or region/serovar	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial												
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
Prairies																				
Derby	13 (28.3)	7	1	2	3			6	3					5						5
Brandenburg	6 (13.0)	6																		
Typhimurium	6 (13.0)	1	1	1	3			5	3					4			3			4
Bovismorbificans	4 (8.7)	3	1					1												
Give	3 (6.5)			3				1						3	3		3			
Ohio	3 (6.5)	3																		
London	2 (4.4)		2						2	2	2	2								
Schwarzengrund	2 (4.4)	1		1				1						1						1
Heidelberg	1 (2.2)			1				1	1											1
4,[5],12:i:-	1 (2.2)	1																		
Infantis	1 (2.2)	1																		
Kiambu	1 (2.2)	1																		
Krefeld	1 (2.2)				1			1	1					1			1			1
Mbandaka	1 (2.2)			1				1						1						1
Senftenberg	1 (2.2)	1																		
Total	**46 (100)**	**25**	**5**	**9**	**7**			**17**	**10**	**2**	**2**	**2**		**15**	**3**		**7**			**13**
Ontario																				
Derby	12 (35.3)	2	1	9				10						9						9
Typhimurium	6 (17.7)	2		2	2			3	3					4			2			3
Worthington	6 (17.7)	5	1																	1
4,[5],12:i:-	4 (11.8)		3		1			1	1					1						4
Give	1 (2.9)	1																		
Infantis	1 (2.9)	1																		
Litchfield	1 (2.9)	1																		
Ouakam	1 (2.9)		1																	1
Rissen	1 (2.9)	1																		
Uganda	1 (2.9)	1																		
Total	**34 (100)**	**14**	**6**	**11**	**3**			**14**	**4**					**14**			**2**			**18**
Québec																				
Typhimurium	11 (36.7)	1		2	8		1	8	9					9	4	3	5			10
Brandenburg	8 (26.7)	5	3											3	3					
Derby	6 (20.0)		1	4	1		1	5	1	1	1	1		5						6
Schwarzengrund	3 (10.0)		3											2	2					1
Mbandaka	1 (3.3)			1				1												1
Ohio	1 (3.3)					1	1	1	1					1	1	1	1			1
Total	**30 (100)**	**6**	**7**	**7**	**9**	**1**	**3**	**15**	**11**	**1**	**1**	**1**		**20**	**10**	**4**	**6**			**19**
National																				
Derby	31 (28.2)	9	3	15	4		1	21	4	1	1	1		19						20
Typhimurium	23 (20.9)	4	1	5	13		1	16	15					17	4	3	10			17
Brandenburg	14 (12.7)	11	3											3	3					
Worthington	6 (5.5)	5	1																	1
Schwarzengrund	5 (4.6)	1	3	1				1						3	2					2
Bovismorbificans	4 (3.6)	3	1					1												
Give	4 (3.6)	1		3				1						3	3		3			
4,[5],12:i:-	4 (3.6)		3		1			1	1					1						4
Ohio	4 (3.6)	3				1	1	1	1					1	1	1	1			1
Less common serovars	15 (13.6)	8	3	3	1			4	4	2	2	2		2			1			5
Total	**110 (100)**	**45**	**18**	**27**	**19**	**1**	**3**	**46**	**25**	**3**	**3**	**3**		**49**	**13**	**4**	**15**			**50**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

Serovars represented by less than 2% of isolates were classified as “Less common serovars”.

The Prairies region includes Alberta, Saskatchewan, and Manitoba.

Table 4. 28 Number of antimicrobial classes in resistance patterns of *Escherichia coli* from pigs, 2016

Province or region	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial											
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
Prairies	246 (45.2)	75	54	81	36		1	89	67	3	2	2		76	21	1	33		1	141
Ontario	155 (28.5)	20	37	70	28		2	66	64	3	5	3		61	16	2	21			126
Québec	143 (26.3)	21	29	57	34	2	4	71	47	5	6	5		67	35	3	30			113
National	**544 (100)**	**116**	**120**	**208**	**98**	**2**	**7**	**226**	**178**	**11**	**13**	**10**		**204**	**72**	**6**	**84**		**1**	**380**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

The Prairies region includes Alberta, Saskatchewan, and Manitoba.

Table 4. 29 Number of antimicrobial classes in resistance patterns of *Salmonella* from turkeys, 2016

Province or region/serovar	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial											
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
British Columbia																				
Hadar	30 (60.0)			30				28	19											30
Agona	11 (22.0)			11			7	11							11					11
Liverpool	4 (8.0)			4			2	4							4					2
Senftenberg	3 (6.0)		3				3	1												
Berta	1 (2.0)	1																		
Idikan	1 (2.0)	1																		
Total	**50 (100)**	**2**	**3**	**45**			**12**	**44**	**19**						**15**					**43**
Ontario																				
Muenchen	22 (31.4)	15		7			1	7							7					7
Albany	11 (15.7)	1	10				9	4												
Agona	8 (11.4)	1		7			6	7							7					
Bredeney	7 (10.0)		5	2			7	1	1	1	1	1			1					1
Schwarzengrund	5 (7.1)	4	1																	1
4,[5],12:i:-	3 (4.3)			2	1		3	3	3						2	1				2
Indiana	3 (4.3)				3			3	3	3	3	3			3		3			3
Livingstone	3 (4.3)		2	1				1												3
Senftenberg	3 (4.3)		1	2			3	1	2											
Less common serovars	5 (7.1)	3		2			2	2	1	1	1	1			2					
Total	**70 (100)**	**24**	**19**	**23**	**4**		**31**	**29**	**10**	**5**	**5**	**5**			**22**	**1**	**3**			**17**
Québec																				
Agona	7 (26.9)	7																		
Rough:z10:e,n,x	5 (19.2)	1	4						4											
Hadar	4 (15.4)	1		3				3	1											3
Schwarzengrund	4 (15.4)	3		1				1							1					1
Heidelberg	2 (7.7)			2			2	2							2					
Typhimurium	2 (7.7)			1	1		1	2	1						2	1				2
Kiambu	1 (3.9)			1			1	1							1					
Muenchen	1 (3.9)	1																		
Total	**26 (100)**	**13**	**4**	**8**	**1**		**4**	**9**	**6**						**6**	**1**				**6**
National																				
Hadar	34 (23.3)	1		33				31	20											33
Agona	26 (17.8)	8		18			13	18							18					11
Muenchen	23 (15.8)	16		7			1	7							7					7
Albany	11 (7.5)	1	10				9	4												
Schwarzengrund	9 (6.2)	7	1	1				1							1					2
Bredeney	7 (4.8)		5	2			7	1	1	1	1	1			1					1
Senftenberg	6 (4.1)		4	2			6	2	2											
Rough:z10:e,n,x	5 (3.4)	1	4						4											
Liverpool	4 (2.7)			4			2	4							4					2
Heidelberg	3 (2.1)			3			3	3	1	1	1	1			3					
4,[5],12:i:-	3 (2.1)			2	1		3	3	3						2	1				2
Indiana	3 (2.1)				3			3	3	3	3	3			3		3			3
Livingstone	3 (2.1)		2	1				1												3
Less common serovars	9 (6.2)	5		3	1		3	4	1						4	1				2
Total	**146 (100)**	**39**	**26**	**76**	**5**		**47**	**82**	**35**	**5**	**5**	**5**			**43**	**2**	**3**			**66**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

Serovars represented by less than 2% of isolates were classified as “Less common serovars”.

Table 4. 30 Number of antimicrobial classes in resistance patterns of *Escherichia coli* from turkeys, 2016

Province or region	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial											
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
British Columbia	116 (41.9)	31	12	53	20		29	67	36	3	2	3		42	8		6		2	74
Ontario	113 (40.8)	25	27	51	10		21	45	27	1		1		33	4		3	1	1	83
Québec	48 (17.3)	12	6	21	9		6	21	20					18	12		2			33
National	**277 (100)**	**68**	**45**	**125**	**39**		**56**	**133**	**83**	**4**	**2**	**4**		**93**	**24**		**11**	**1**	**3**	**190**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

Table 4. 31 Number of antimicrobial classes in resistance patterns of *Campylobacter* from turkeys, 2016

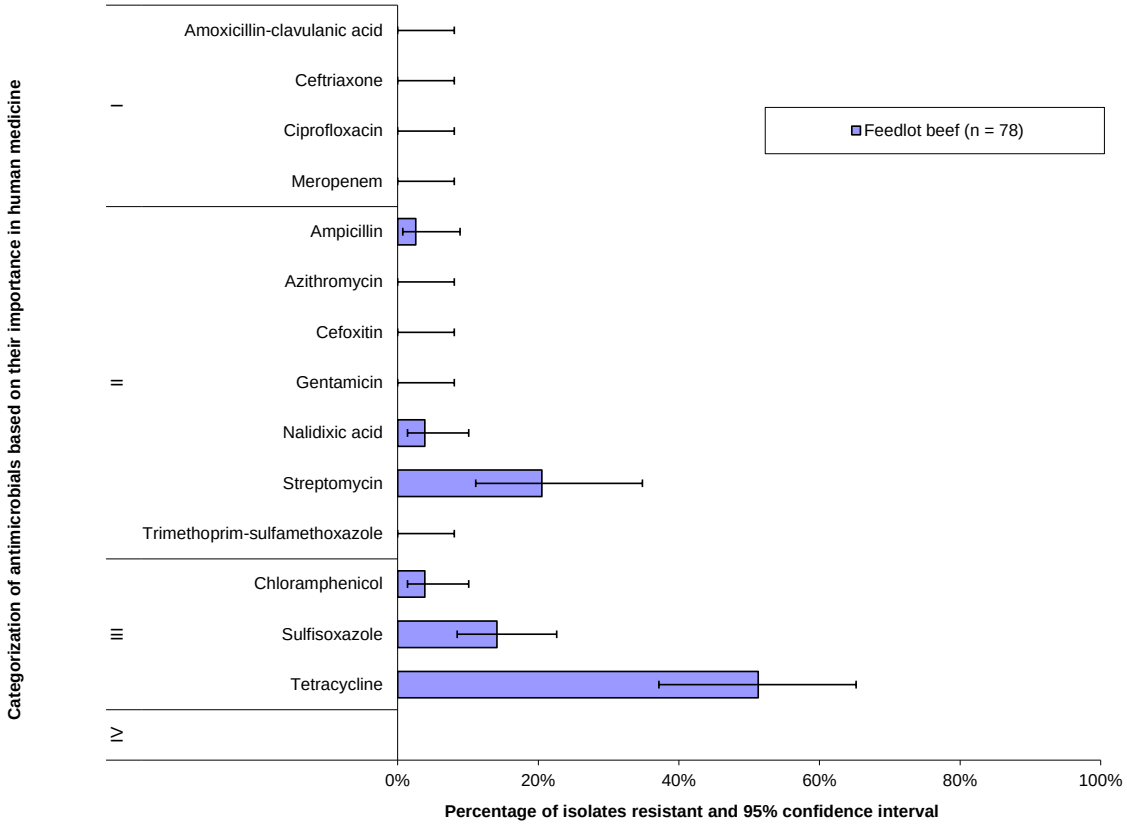
Province or region/species	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial								
							Aminoglycosides	Ketolides	Lincosamides	Macrolides		Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	TEL	CLI	AZM	ERY	FLR	CIP	NAL	TET
British Columbia															
Campylobacter coli	24 (30.4)	7	16	1									17	17	1
Campylobacter jejuni	55 (69.6)	30	17	8									20	20	13
Total	**79 (100)**	**37**	**33**	**9**									**37**	**37**	**14**
Ontario															
Campylobacter coli	27 (41.5)	10	15	2				2		2	2		2	2	15
Campylobacter jejuni	38 (58.5)	7	30	1									1	1	31
Total	**65 (100)**	**17**	**45**	**3**				**2**		**2**	**2**		**3**	**3**	**46**
Québec															
Campylobacter coli	13 (48.1)	6	7												7
Campylobacter jejuni	14 (51.9)	9	5												5
Total	**27 (100)**	**15**	**12**												**12**
National															
Campylobacter coli	64 (37.4)	23	38	3				2		2	2		19	19	23
Campylobacter jejuni	107 (62.6)	46	52	9									21	21	49
Total	**171 (100)**	**69**	**90**	**12**				**2**		**2**	**2**		**40**	**40**	**72**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

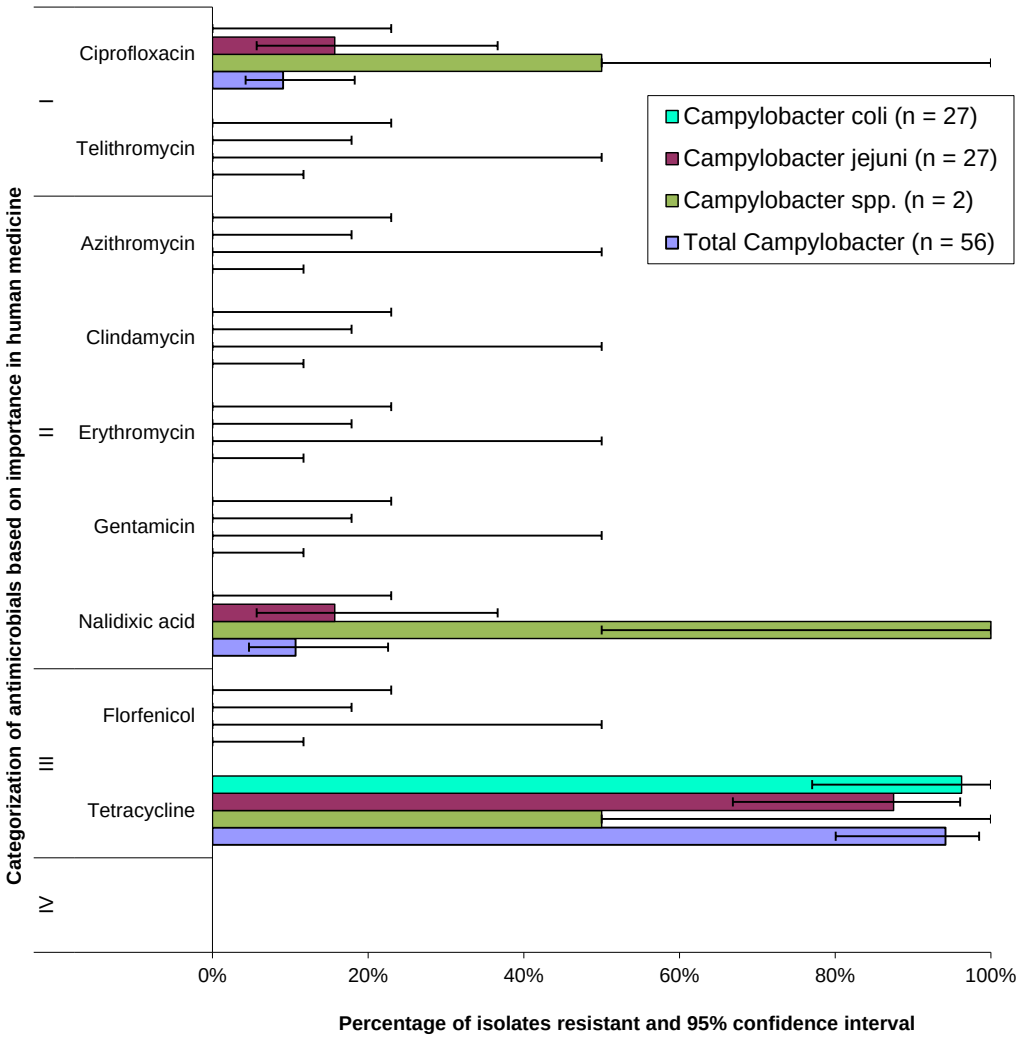
Temporal antimicrobial resistance summary

Figure 4. 27 Resistance of *Escherichia coli* isolates from feedlot beef cattle, 2016



The proportion of resistant isolates for all antimicrobials was adjusted to account for multiple samples per feedlot.

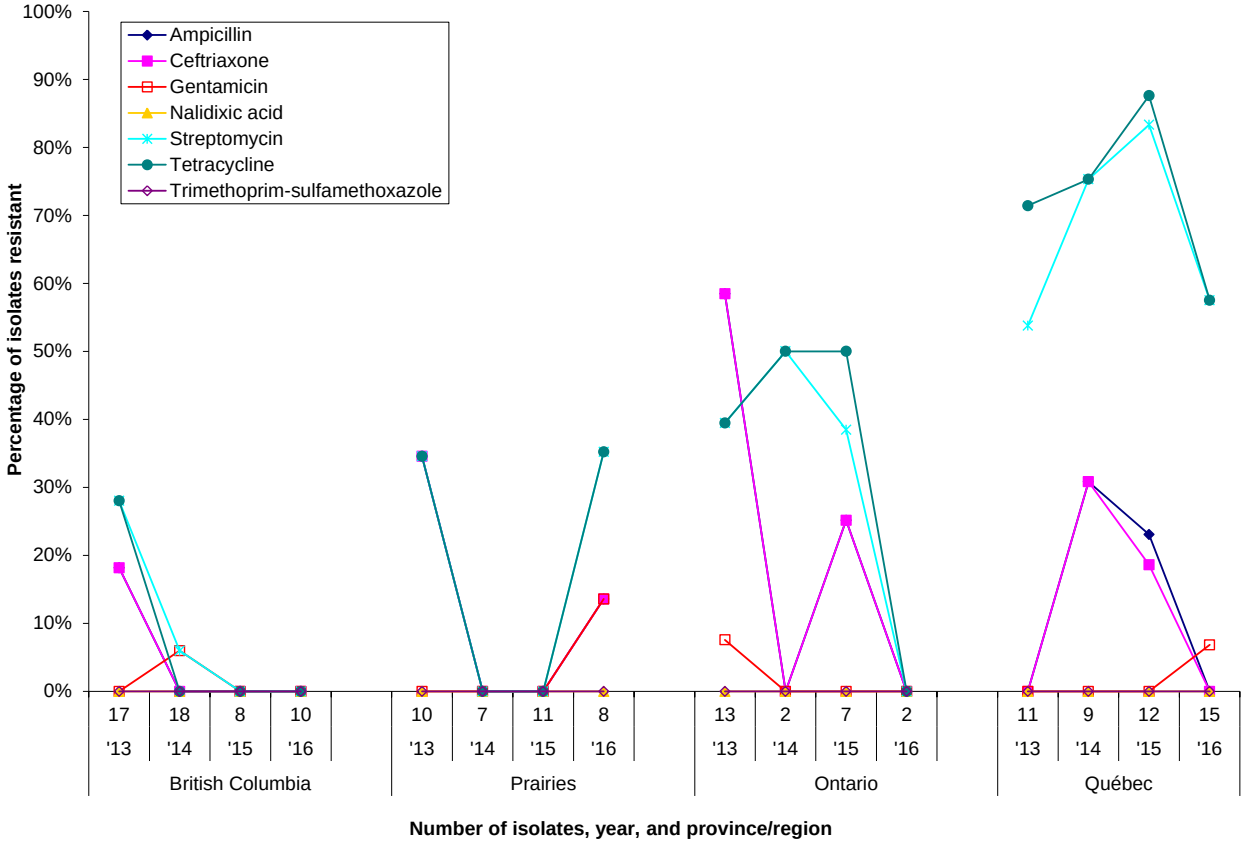
Figure 4. 28 Resistance of *Campylobacter* isolates from feedlot beef cattle, 2016



This figure summarizes the proportion (%, adjusted to account for multiple samples per herd) of isolates resistant to a specific antimicrobial for the 2016 sampling year.

Campylobacter spp. include unidentified species, some of which may be intrinsically resistant to nalidixic acid.

Figure 4. 29 Temporal variations in resistance of *Salmonella* isolates from chicks and barn environment at placement, 2013 to 2016



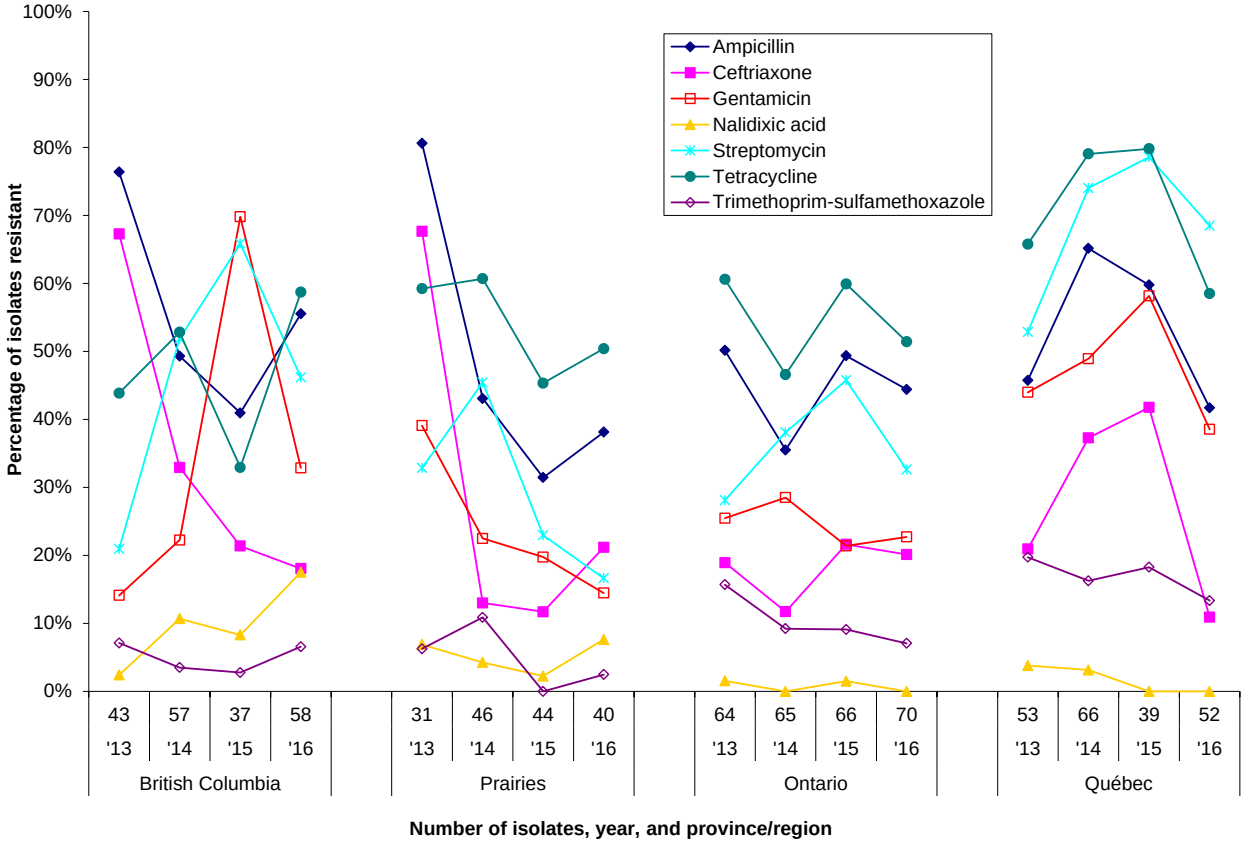
Province/region	British Columbia				Prairies				Ontario				Québec			
Year	'13	'14	'15	'16	'13	'14	'15	'16	'13	'14	'15	'16	'13	'14	'15	'16
Number of isolates	17	18	8	10	10	7	11	8	13	2	7	2	11	9	12	15
Antimicrobial																
Ampicillin	**18%**	0%	**0%**	**0%**	**35%**	0%	**0%**	**14%**	**58%**	0%	**25%**	**0%**	**0%**	31%	**23%**	**0%**
Ceftriaxone	**18%**	0%	**0%**	**0%**	**35%**	0%	**0%**	**14%**	**58%**	0%	**25%**	**0%**	**0%**	31%	**19%**	**0%**
Gentamicin	**0%**	6%	**0%**	**0%**	**0%**	0%	**0%**	**14%**	**8%**	0%	**0%**	**0%**	**0%**	0%	**0%**	**7%**
Nalidixic acid	**0%**	0%	**0%**	**0%**	**0%**	0%	**0%**	**0%**	**0%**	0%	**0%**	**0%**	**0%**	0%	**0%**	**0%**
Streptomycin	**28%**	6%	**0%**	**0%**	**35%**	0%	**0%**	**35%**	**39%**	50%	**38%**	**0%**	**54%**	75%	**83%**	**58%**
Tetracycline	**28%**	0%	**0%**	**0%**	**35%**	0%	**0%**	**35%**	**39%**	50%	**50%**	**0%**	**71%**	75%	**88%**	**58%**
Trimethoprim-sulfamethoxazole	**0%**	0%	**0%**	**0%**	**0%**	0%	**0%**	**0%**	**0%**	0%	**0%**	**0%**	**0%**	0%	**0%**	**0%**

The proportion of resistant isolates for all antimicrobials was adjusted to account for multiple samples per flock.

For the temporal analyses by province/region, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the first surveillance year and the preceding surveillance year (grey areas). The presence of blue areas indicate significant differences ($P \leq 0.05$) for a given province/region and antimicrobial.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Figure 4. 30 Temporal variations in resistance of *Escherichia coli* isolates from chicks and barn environment at placement, 2013 to 2016



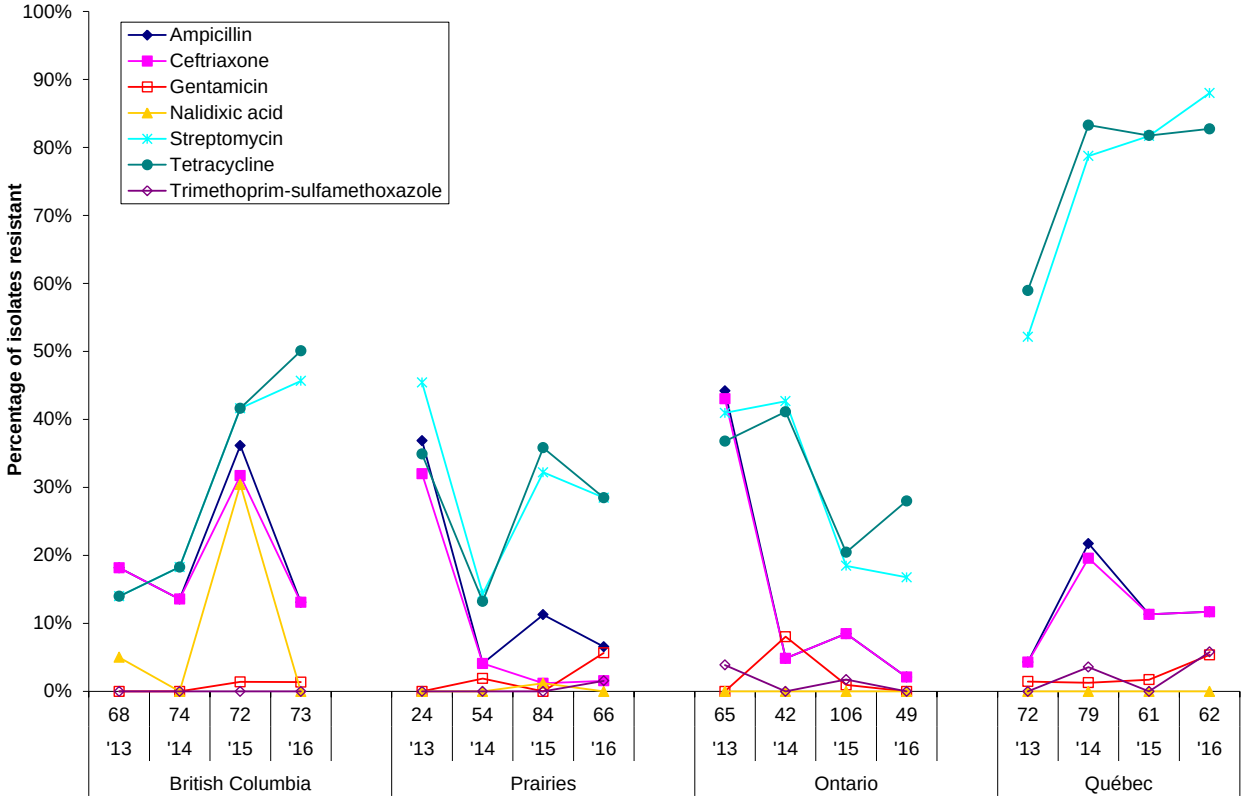
Province/region	British Columbia				Prairies				Ontario				Québec			
Year	'13	'14	'15	'16	'13	'14	'15	'16	'13	'14	'15	'16	'13	'14	'15	'16
Number of isolates	43	57	37	58	31	46	44	40	64	65	66	70	53	66	39	52
Antimicrobial																
Ampicillin	**76%**	49%	**41%**	**56%**	**81%**	43%	**31%**	**38%**	**50%**	36%	**49%**	**44%**	**46%**	65%	**60%**	**42%**
Ceftriaxone	**67%**	33%	**21%**	**18%**	**68%**	13%	**12%**	**21%**	**19%**	12%	**22%**	**20%**	**21%**	37%	**42%**	**11%**
Gentamicin	**14%**	22%	**70%**	**33%**	**39%**	22%	**20%**	**14%**	**25%**	28%	**21%**	**23%**	**44%**	49%	**58%**	**39%**
Nalidixic acid	**2%**	11%	**8%**	**18%**	**7%**	4%	**2%**	**8%**	**2%**	0%	**2%**	**0%**	**4%**	3%	**0%**	**0%**
Streptomycin	**21%**	52%	**66%**	**46%**	**33%**	45%	**23%**	**17%**	**28%**	38%	**46%**	**33%**	**53%**	74%	**79%**	**68%**
Tetracycline	**44%**	53%	**33%**	**59%**	**59%**	61%	**45%**	**50%**	**61%**	47%	**60%**	**51%**	**66%**	79%	**80%**	**58%**
Trimethoprim-sulfamethoxazole	**7%**	3%	**3%**	**7%**	**6%**	11%	**0%**	**2%**	**16%**	9%	**9%**	**7%**	**20%**	16%	**18%**	**13%**

The proportion of resistant isolates for all antimicrobials was adjusted to account for multiple samples per flock.

For the temporal analyses by province/region, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the first surveillance year and the preceding surveillance year (grey areas). The presence of blue areas indicate significant differences ($P \leq 0.05$) for a given province/region and antimicrobial.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Figure 4. 31 Temporal variations in resistance of *Salmonella* isolates from chickens at pre-harvest, 2013 to 2016



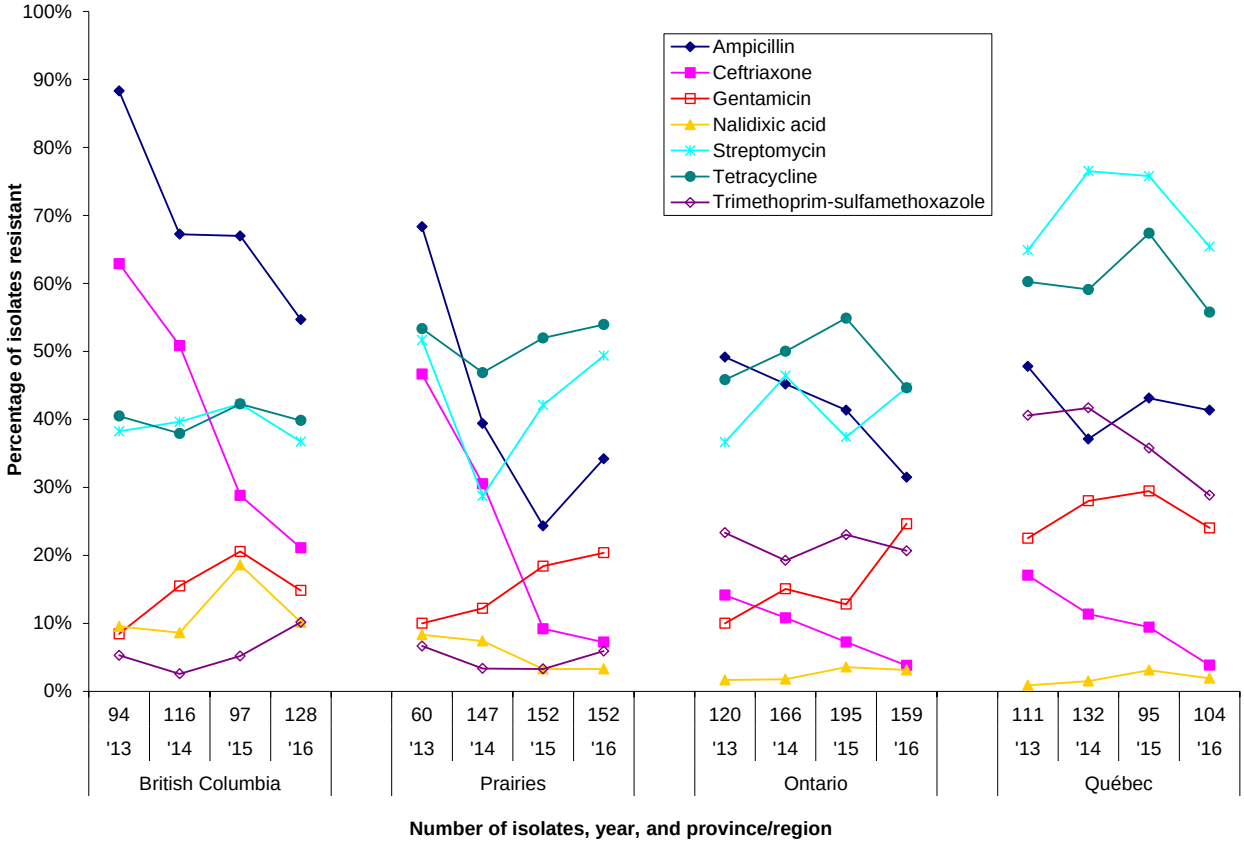
Province/region	British Columbia				Prairies				Ontario				Québec			
Year	'13	'14	'15	'16	'13	'14	'15	'16	'13	'14	'15	'16	'13	'14	'15	'16
Number of isolates	68	74	72	73	24	54	84	66	65	42	106	49	72	79	61	62
Antimicrobial																
Ampicillin	**18%**	14%	**36%**	**13%**	**37%**	4%	**11%**	**7%**	**44%**	5%	**8%**	**2%**	**4%**	22%	**11%**	**12%**
Ceftriaxone	**18%**	14%	**32%**	**13%**	**32%**	4%	**1%**	**2%**	**43%**	5%	**8%**	**2%**	**4%**	20%	**11%**	**12%**
Gentamicin	**0%**	0%	**1%**	**1%**	**0%**	2%	**0%**	**6%**	**0%**	8%	**1%**	**0%**	**1%**	1%	**2%**	**5%**
Nalidixic acid	**5%**	0%	**30%**	**0%**	**0%**	0%	**1%**	**0%**	**0%**	0%	**0%**	**0%**	**0%**	0%	**0%**	**0%**
Streptomycin	**14%**	18%	**42%**	**46%**	**45%**	14%	**32%**	**28%**	**41%**	43%	**18%**	**17%**	**52%**	79%	**82%**	**88%**
Tetracycline	**14%**	18%	**42%**	**50%**	**35%**	13%	**36%**	**28%**	**37%**	41%	**20%**	**28%**	**59%**	83%	**82%**	**83%**
Trimethoprim-sulfamethoxazole	**0%**	0%	**0%**	**0%**	**0%**	0%	**0%**	**2%**	**4%**	0%	**2%**	**0%**	**0%**	4%	**0%**	**6%**

The proportion of resistant isolates for all antimicrobials was adjusted to account for multiple samples per flock.

For the temporal analyses by province/region, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the first surveillance year and the preceding surveillance year (grey areas). The presence of blue areas indicate significant differences ($P \leq 0.05$) for a given province/region and antimicrobial.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Figure 4. 32 Temporal variations in resistance of *Escherichia coli* isolates from chickens at pre-harvest, 2013 to 2016



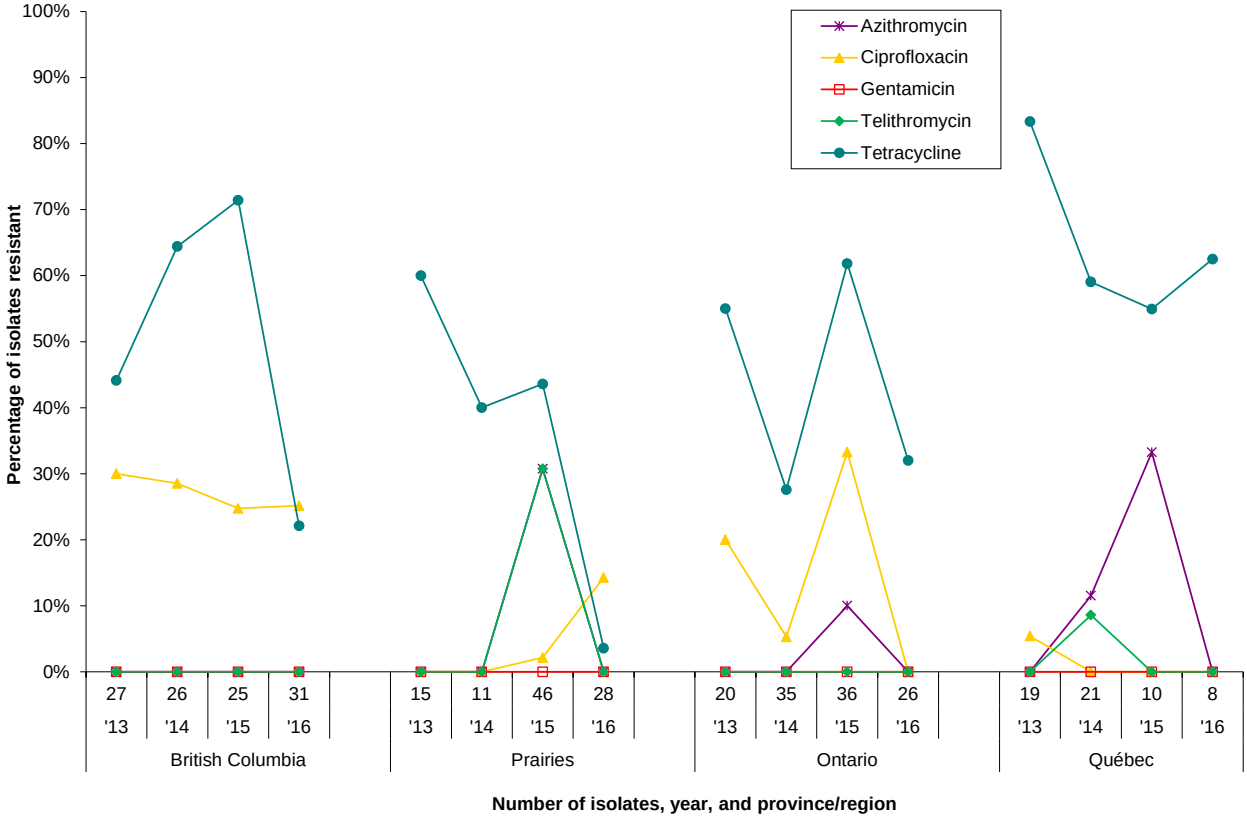
Province/region	British Columbia				Prairies				Ontario				Québec			
Year	'13	'14	'15	'16	'13	'14	'15	'16	'13	'14	'15	'16	'13	'14	'15	'16
Number of isolates	94	116	97	128	60	147	152	152	120	166	195	159	111	132	95	104
Antimicrobial																
Ampicillin	**88%**	67%	**67%**	**55%**	**68%**	39%	**24%**	**34%**	**49%**	45%	**41%**	**31%**	**48%**	37%	**43%**	**41%**
Ceftriaxone	**63%**	51%	**29%**	**21%**	**47%**	31%	**9%**	**7%**	**14%**	11%	**7%**	**4%**	**17%**	11%	**9%**	**4%**
Gentamicin	**8%**	16%	**21%**	**15%**	**10%**	12%	**18%**	**20%**	**10%**	15%	**13%**	**25%**	**23%**	28%	**29%**	**24%**
Nalidixic acid	**10%**	9%	**19%**	**10%**	**8%**	7%	**3%**	**3%**	**2%**	2%	**4%**	**3%**	**1%**	2%	**3%**	**2%**
Streptomycin	**38%**	40%	**42%**	**37%**	**52%**	29%	**42%**	**49%**	**37%**	46%	**37%**	**45%**	**65%**	77%	**76%**	**65%**
Tetracycline	**40%**	38%	**42%**	**40%**	**53%**	47%	**52%**	**54%**	**46%**	50%	**55%**	**45%**	**60%**	59%	**67%**	**56%**
Trimethoprim-sulfamethoxazole	**5%**	3%	**5%**	**10%**	**7%**	3%	**3%**	**6%**	**23%**	19%	**23%**	**21%**	**41%**	42%	**36%**	**29%**

The proportion of resistant isolates for all antimicrobials was adjusted to account for multiple samples per flock.

For the temporal analyses by province/region, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the first surveillance year and the preceding surveillance year (grey areas). The presence of blue areas indicate significant differences ($P \leq 0.05$) for a given province/region and antimicrobial.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Figure 4. 33 Temporal variations in resistance of *Campylobacter* isolates from chickens at pre-harvest, 2013 to 2016



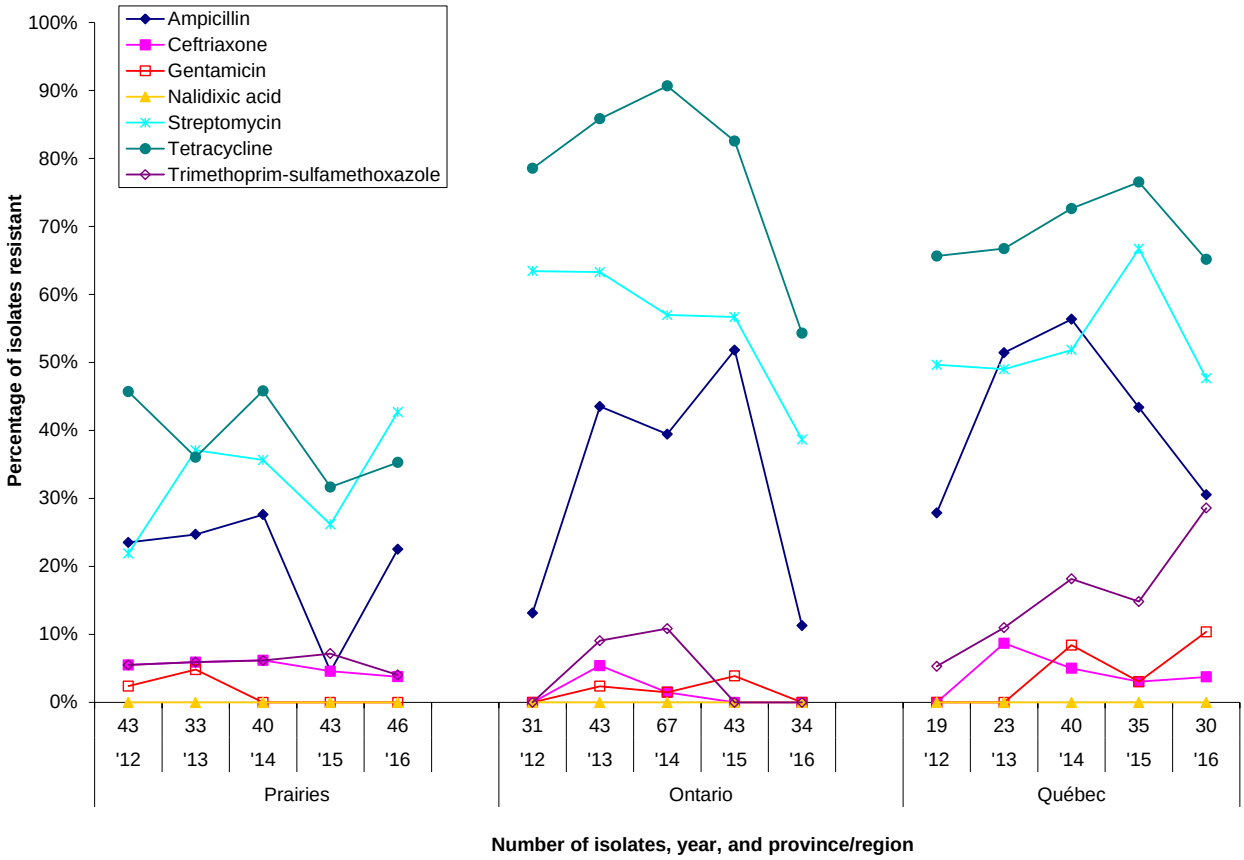
Province/region	British Columbia				Prairies				Ontario				Québec			
Year	'13	'14	'15	'16	'13	'14	'15	'16	'13	'14	'15	'16	'13	'14	'15	'16
Number of isolates	27	26	25	31	15	11	46	28	20	35	36	26	19	21	10	8
Antimicrobial																
Azithromycin	**0%**	0%	**0%**	**0%**	**0%**	0%	**31%**	**0%**	**0%**	0%	**10%**	**0%**	**0%**	12%	**33%**	**0%**
Ciprofloxacin	**30%**	29%	**25%**	**25%**	**0%**	0%	**2%**	**14%**	**20%**	5%	**33%**	**0%**	**5%**	0%	**0%**	**0%**
Gentamicin	**0%**	0%	**0%**	**0%**	**0%**	0%	**0%**	**0%**	**0%**	0%	**0%**	**0%**	**0%**	0%	**0%**	**0%**
Telithromycin	**0%**	0%	**0%**	**0%**	**0%**	0%	**31%**	**0%**	**0%**	0%	**0%**	**0%**	**0%**	9%	**0%**	**0%**
Tetracycline	**44%**	64%	**71%**	**22%**	**60%**	40%	**44%**	**4%**	**55%**	28%	**62%**	**32%**	**83%**	59%	**55%**	**63%**

The proportion of resistant isolates for all antimicrobials was adjusted to account for multiple samples per flock.

For the temporal analyses by province/region, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the first surveillance year and the preceding surveillance year (grey areas). The presence of blue areas indicate significant differences ($P \leq 0.05$) for a given province/region and antimicrobial.

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Figure 4. 34 Temporal variations in resistance of *Salmonella* isolates from pigs, 2012 to 2016



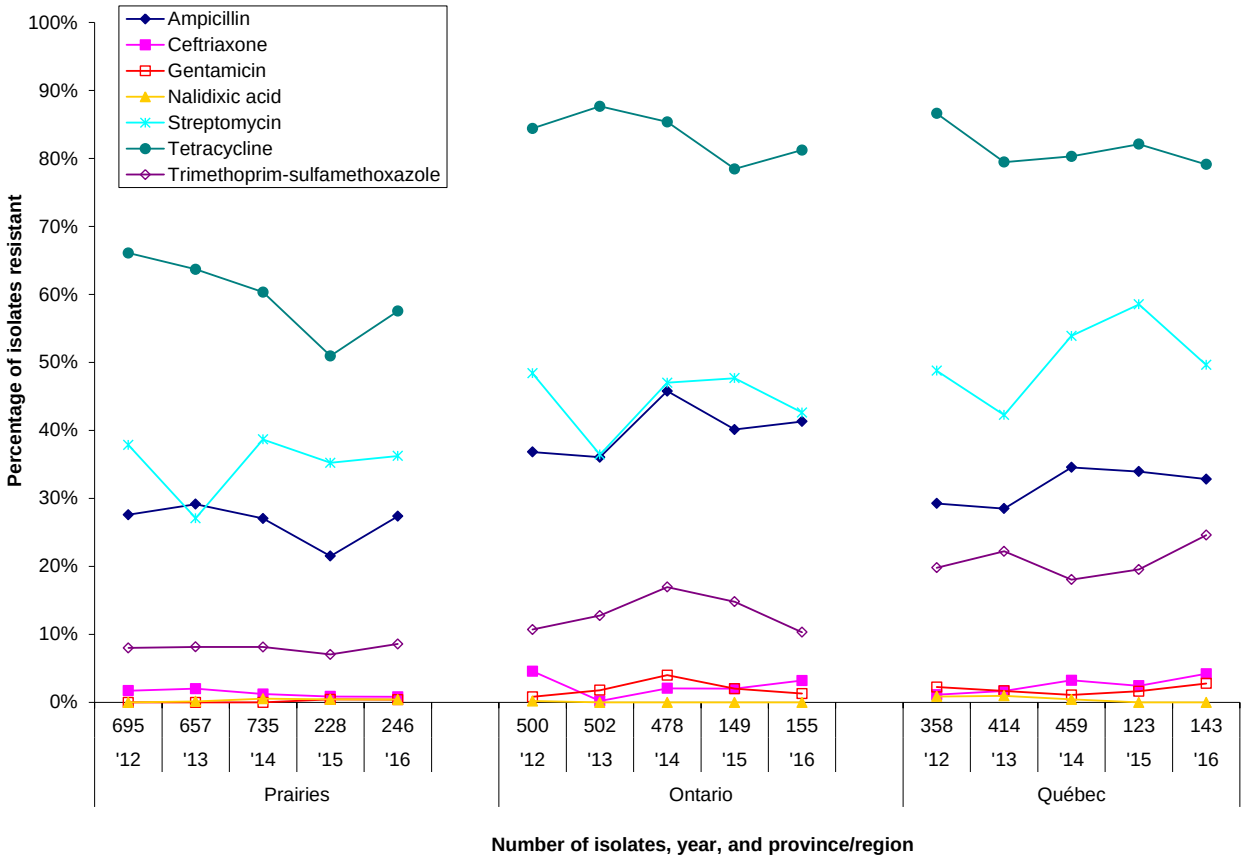
Province/region	Prairies					Ontario					Québec				
Year	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16
Number of isolates	43	33	40	43	46	31	43	67	43	34	19	23	40	35	30
Antimicrobial															
Ampicillin	**24%**	25%	28%	**5%**	**23%**	**13%**	44%	39%	**52%**	**11%**	**28%**	51%	56%	**43%**	**31%**
Cefriaxone	**6%**	6%	6%	**5%**	**4%**	**0%**	5%	1%	**0%**	**0%**	**0%**	9%	5%	**3%**	**4%**
Gentamicin	**2%**	5%	0%	**0%**	**0%**	**0%**	2%	1%	**4%**	**0%**	**0%**	0%	8%	**3%**	**10%**
Nalidixic acid	**0%**	0%	0%	**0%**	**0%**	**0%**	0%	0%	**0%**	**0%**	**0%**	0%	0%	**0%**	**0%**
Streptomycin	**22%**	37%	36%	**26%**	**43%**	**63%**	63%	57%	**57%**	**39%**	**50%**	49%	52%	**67%**	**48%**
Tetracycline	**46%**	36%	46%	**32%**	**35%**	**79%**	86%	91%	**83%**	**54%**	**66%**	67%	73%	**77%**	**65%**
Trimethoprim-sulfamethoxazole	**6%**	6%	6%	**7%**	**4%**	**0%**	9%	11%	**0%**	**0%**	**5%**	11%	18%	**15%**	**29%**

The proportion of resistant isolates for all antimicrobials was adjusted to account for multiple samples per herd.

For the temporal analyses by province/region, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the previous 5 years and the preceding surveillance year (grey areas). The presence of blue areas indicate significant differences ($P \leq 0.05$) for a given province/region and antimicrobial.

The Prairies region includes Alberta, Saskatchewan, and Manitoba.

Figure 4. 35 Temporal variations in resistance of *Escherichia coli* isolates from pigs, 2012 to 2016



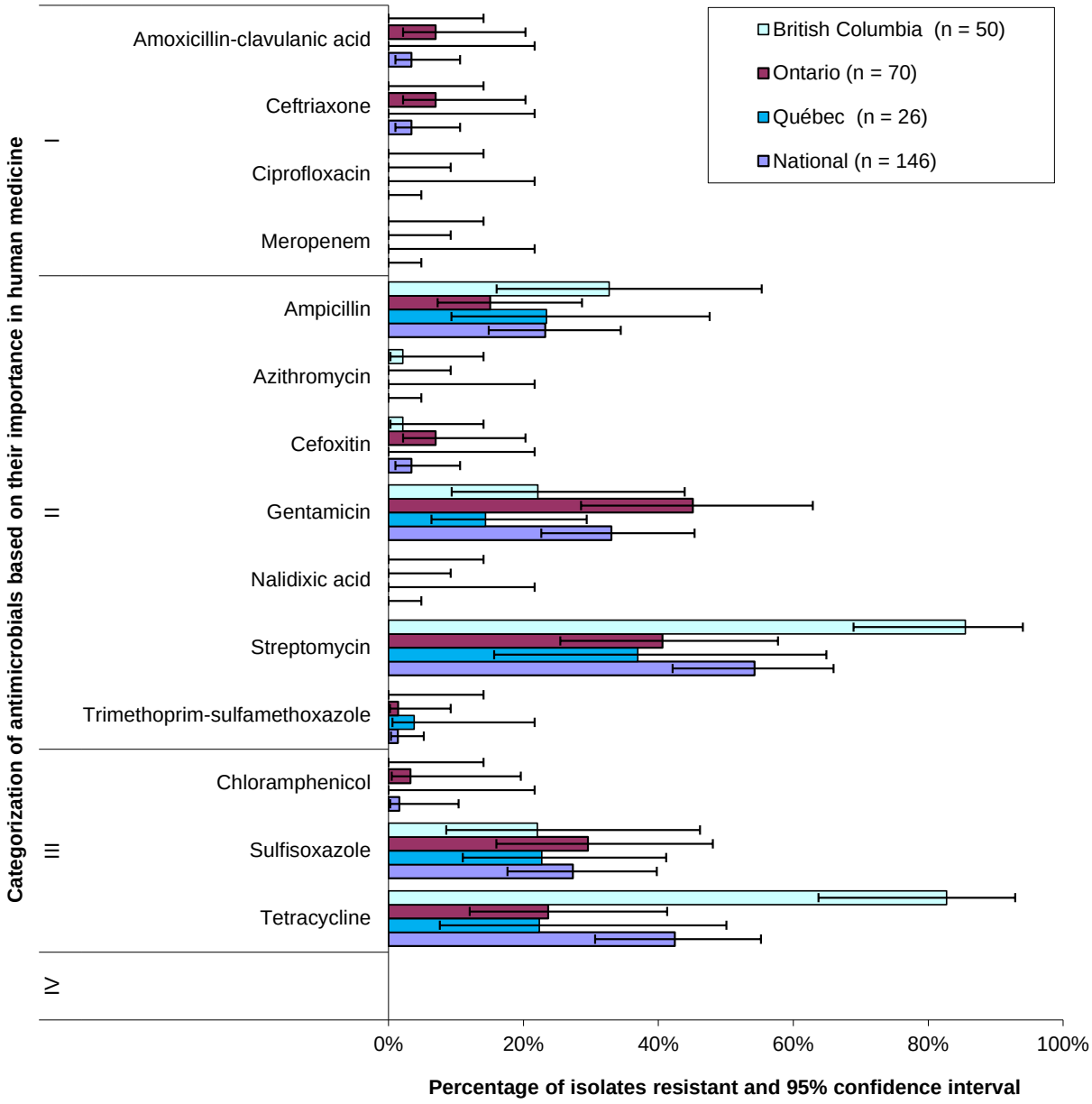
Province/region	Prairies					Ontario					Québec				
Year	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16	'12	'13	'14	'15	'16
Number of isolates	695	657	735	228	246	500	502	478	149	155	358	414	459	123	143
Antimicrobial															
Ampicillin	**28%**	29%	27%	**22%**	**27%**	**37%**	36%	46%	**40%**	**41%**	**29%**	28%	35%	**34%**	**33%**
Cefriaxone	**2%**	2%	1%	**1%**	**1%**	**5%**	0%	2%	**2%**	**3%**	**1%**	2%	3%	**2%**	**4%**
Gentamicin	**0%**	0%	0%	**0%**	**0%**	**1%**	2%	4%	**2%**	**1%**	**2%**	2%	1%	**2%**	**3%**
Nalidixic acid	**0%**	0%	1%	**0%**	**0%**	**0%**	0%	0%	**0%**	**0%**	**1%**	1%	0%	**0%**	**0%**
Streptomycin	**38%**	27%	39%	**35%**	**36%**	**48%**	36%	47%	**48%**	**43%**	**49%**	42%	54%	**59%**	**50%**
Tetracycline	**66%**	64%	60%	**51%**	**58%**	**84%**	88%	85%	**78%**	**81%**	**87%**	79%	80%	**82%**	**79%**
Trimethoprim-sulfamethoxazole	**8%**	8%	8%	**7%**	**9%**	**11%**	13%	17%	**15%**	**10%**	**20%**	22%	18%	**20%**	**25%**

The proportion of resistant isolates for all antimicrobials was adjusted to account for multiple samples per herd.

For the temporal analyses by province/region, the proportion (%) of isolates resistant to a specific antimicrobial over the current year has been compared to the proportion (%) of isolates resistant to the same antimicrobial during the previous 5 years and the preceding surveillance year (grey areas). The presence of blue areas indicate significant differences ($P \leq 0.05$) for a given province/region and antimicrobial.

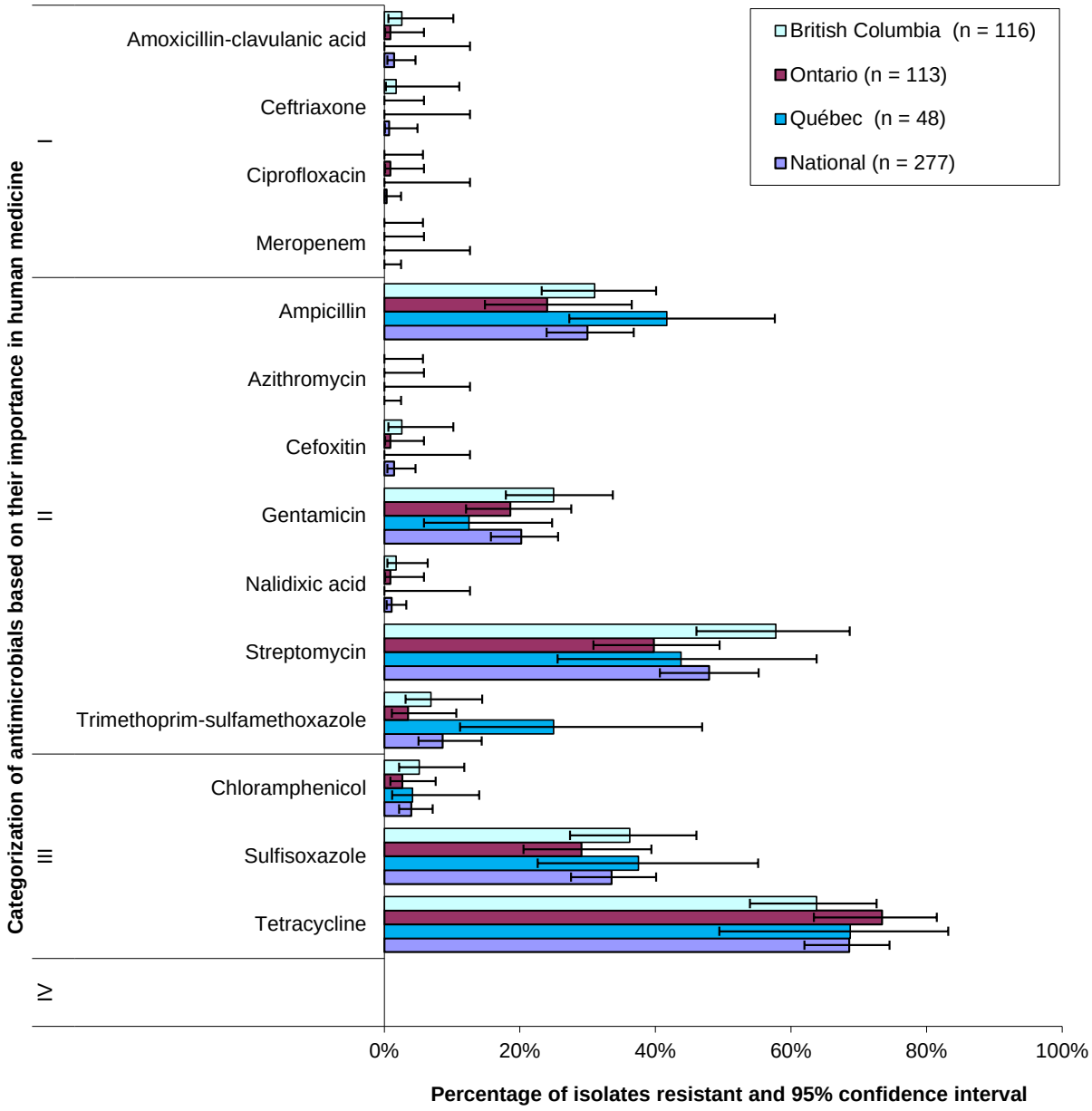
The Prairies region includes Alberta, Saskatchewan, and Manitoba.

Figure 4. 36 Resistance of *Salmonella* isolates from turkeys, 2016



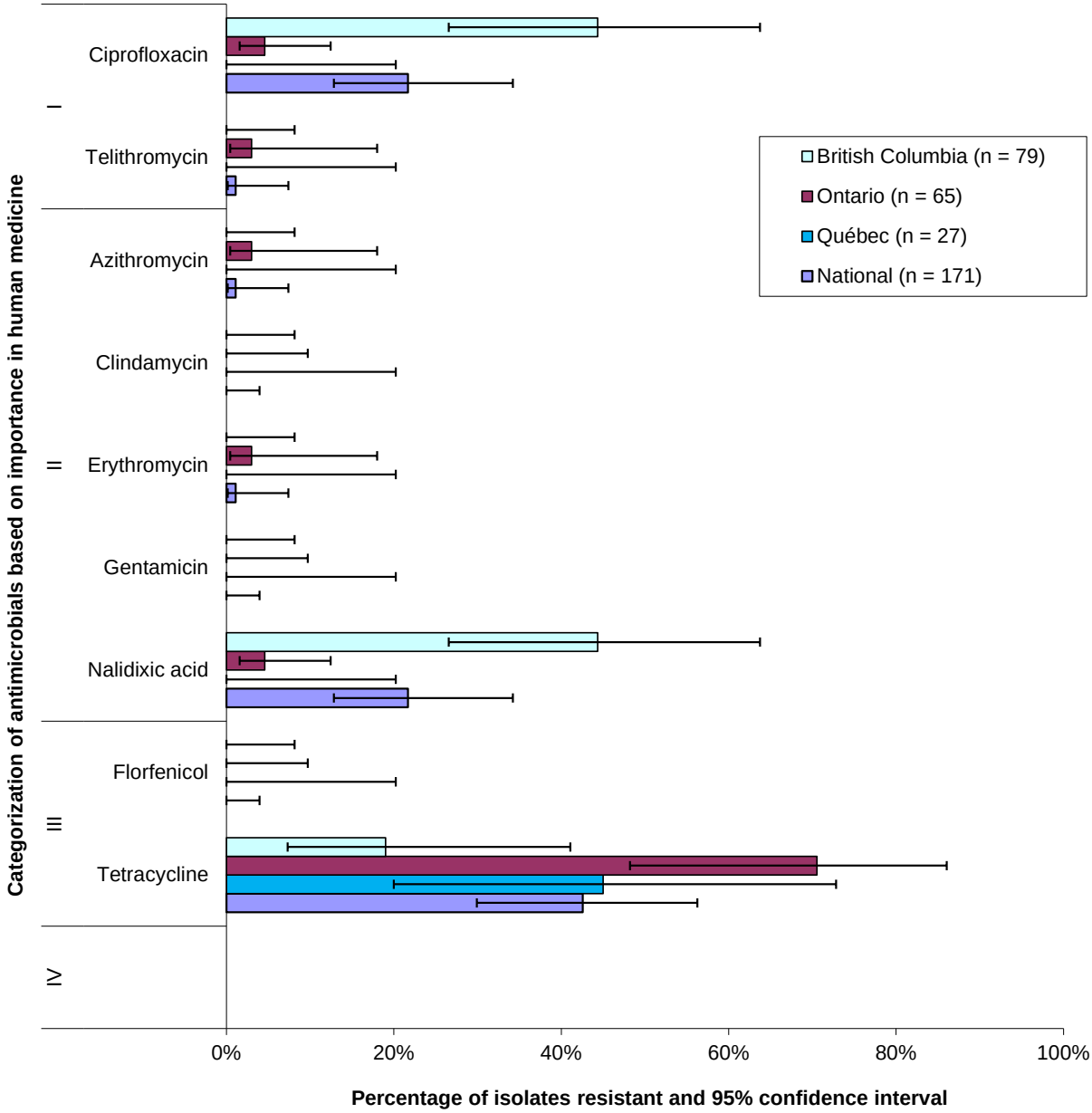
The proportion of resistant isolates for all antimicrobials was adjusted to account for multiple samples per flock.

Figure 4. 37 Resistance of *Escherichia coli* isolates from turkey, 2016



The proportion of resistant isolates for all antimicrobials was adjusted to account for multiple samples per flock.

Figure 4. 38 Resistance of *Campylobacter* isolates from turkeys, 2016



The proportion of resistant isolates for all antimicrobials was adjusted to account for multiple samples per flock.

Recovery results

Table 4. 32 Farm Surveillance recovery rates in feedlot beef, 2016

Animal species	Province/region	Year	Percentage (%) of isolates recovered and number of isolates recovered / number of samples submitted							
			Escherichia coli		*Salmonella*		*Campylobacter*		*Enterococcus*	
Feedlot beef	National	2016	**100%**	78/78	**4%**	3/78	**72%**	56/78		

Grey-shaded areas indicate either: a) isolates recovered from sampling activities outside the scope of CIPARS routine (or "core") surveillance in the specified year (i.e. grey-shaded areas with data) or b) discontinuation or no surveillance activity (i.e. grey-shaded areas with no data).

Table 4. 33 Farm Surveillance recovery rates in chickens, 2013 to 2016

Animal species	Province/region	Year	Percentage (%) of isolates recovered and number of isolates recovered / number of samples submitted							
			Escherichia coli		*Salmonella*		*Campylobacter*		*Enterococcus*	
Chickens (Chick placement)	British Columbia	2013	**72%**	43/60	**28%**	17/60				
		2014	**71%**	57/80	**23%**	18/80				
		2015	**74%**	37/50	**16%**	8/50				
		2016	**68%**	58/85	**12%**	10/85				
	Prairies	2013	**89%**	31/35	**29%**	10/35				
		2014	**82%**	46/56	**13%**	7/56				
		2015	**80%**	44/55	**20%**	11/55				
		2016	**73%**	40/55	**15%**	8/55				
	Ontario	2013	**85%**	64/75	**17%**	13/75				
		2014	**87%**	65/75	**3%**	2/75				
		2015	**88%**	66/75	**9%**	7/75				
		2016	**93%**	70/75	**3%**	2/75				
	Québec	2013	**82%**	53/65	**17%**	11/65				
		2014	**83%**	66/80	**11%**	9/80				
		2015	**87%**	39/45	**27%**	12/45				
		2016	**74%**	52/70	**21%**	15/70				
	National	2013	**81%**	191/235	**22%**	51/235				
		2014	**80%**	234/291	**12%**	36/291				
		2015	**83%**	186/225	**17%**	38/225				
		2016	**77%**	220/285	**12%**	35/285				
Chickens (Pre-harvest)	British Columbia	2013	**98%**	94/96	**71%**	68/96	**28%**	27/96		
		2014	**100%**	116/116	**64%**	74/116	**22%**	26/116		
		2015	**97%**	97/100	**72%**	72/100	**25%**	25/100		
		2016	**100%**	128/128	**57%**	73/128	**24%**	31/128		
	Prairies	2013	**100%**	60/60	**40%**	24/60	**25%**	15/60		
		2014	**99%**	147/148	**36%**	54/148	**7%**	11/148		
		2015	**100%**	152/152	**55%**	84/152	**30%**	46/152		
		2016	**100%**	152/152	**43%**	66/152	**18%**	28/152		
	Ontario	2013	**100%**	120/120	**54%**	65/120	**17%**	20/120		
		2014	**99%**	166/168	**25%**	42/168	**21%**	35/168		
		2015	**99%**	195/196	**54%**	106/196	**18%**	36/196		
		2016	**99%**	159/160	**31%**	49/160	**16%**	26/160		
	Québec	2013	**99%**	111/112	**64%**	72/112	**17%**	19/112		
		2014	**100%**	132/132	**60%**	79/132	**16%**	21/132		
		2015	**99%**	95/96	**64%**	61/96	**10%**	10/96		
		2016	**100%**	104/104	**61%**	63/104	**8%**	8/104		
	National	2013	**99%**	385/388	**59%**	229/388	**20%**	81/388		
		2014	**99%**	561/564	**44%**	249/564	**16%**	93/564		
		2015	**99%**	539/544	**59%**	323/544	**22%**	117/544		
		2016	**99%**	543/544	**46%**	251/544	**17%**	93/544		

Grey-shaded areas indicate either: a) isolates recovered from sampling activities outside the scope of CIPARS routine (or "core") surveillance in the specified year (i.e. grey-shaded areas with data) or b) discontinuation or no surveillance activity (i.e. grey-shaded areas with no data).

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Table 4. 34 Farm Surveillance recovery rates in pigs, 2006 to 2016

Animal species	Province/region	Year	Percentage (%) of isolates recovered and number of isolates recovered / number of samples submitted							
			Escherichia coli		*Salmonella*		*Campylobacter*		*Enterococcus*	
Pigs	Prairies	2012	**100%**	232/232	**19%**	43/232				
		2013	**98%**	224/228	**14%**	33/228				
		2014	**99%**	248/252	**16%**	40/252				
		2015	**97%**	228/234	**18%**	43/234				
		2016	**98%**	246/252	**18%**	46/252				
	Ontario	2012	**99%**	167/168	**18%**	31/168				
		2013	**100%**	168/168	**26%**	43/168				
		2014	**100%**	162/162	**41%**	67/162				
		2015	**99%**	149/150	**29%**	43/150				
		2016	**99%**	155/156	**22%**	34/156				
	Québec	2012	**100%**	120/120	**16%**	19/120				
		2013	**100%**	138/138	**17%**	23/138				
		2014	**100%**	156/156	**26%**	40/156				
		2015	**98%**	123/126	**28%**	35/126				
		2016	**99%**	143/144	**21%**	30/144				
	National	2006	**99%**	459/462	**20%**	94/462			**81%**	374/462
		2007	**100%**	612/612	**21%**	136/612			**81%**	495/612
		2008	**99%**	481/486	**13%**	61/486			**92%**	448/486
		2009	**99%**	695/698	**18%**	124/698			**97%**	680/698
		2010	**99%**	566/569	**18%**	101/569			**96%**	545/569
		2011	**100%**	560/560	**14%**	77/560				
		2012	**99%**	519/520	**18%**	93/520				
		2013	**99%**	530/534	**19%**	99/534				
		2014	**99%**	566/570	**26%**	147/570				
		2015	**98%**	500/510	**24%**	121/510				
		2016	**99%**	544/552	**20%**	110/552				

Grey-shaded areas indicate either: a) isolates recovered from sampling activities outside the scope of CIPARS routine (or "core") surveillance in the specified year (i.e. grey-shaded areas with data) or b) discontinuation or no surveillance activity (i.e. grey-shaded areas with no data).

The Prairies is a region including the provinces of Alberta and Saskatchewan.

Table 4. 35 Farm Surveillance recovery rates in turkeys, 2016

Animal species	Province / region	Year	Percentage (%) of isolates recovered and number of isolates recovered / number of samples submitted							
			Escherichia coli		*Salmonella*		*Campylobacter*		*Enterococcus*	
Turkeys	British Columbia	2016	**100%**	116/116	**43%**	50/116	**68%**	79/116		
	Ontario	2016	**97%**	113/116	**60%**	70/116	**56%**	65/116		
	Québec	2016	**100%**	48/48	**54%**	26/48	**56%**	27/48		
	National	2016	**99%**	277/280	**52%**	146/280	**61%**	171/280		

Grey-shaded areas indicate either: a) isolates recovered from sampling activities outside the scope of CIPARS routine (or "core") surveillance in the specified year (i.e. grey-shaded areas with data) or b) discontinuation or no surveillance activity (i.e. grey-shaded areas with no data).

Surveillance of Animal Clinical Isolates

Key findings

Cattle

Salmonella (n = 207)

Dublin was the most common serovar recovered from cattle (37%, 76/207). Twenty of these isolates (57%, 43/76) were resistant to 6 antimicrobial classes tested (all except the macrolides). All the Dublin isolates resistant to 6 antimicrobial classes were from Ontario (n = 33) and Québec (n = 10). Dublin isolates, regardless of resistance, were from Ontario (n = 43), Québec (n = 22), Manitoba (n = 6) and British Columbia (n = 5) (Table 4. 36).

The second most common serotype observed in cattle was Typhimurium (30%, 62/207). Just 3 Typhimurium isolates (5%, 3/62) demonstrated resistance to 6 antimicrobial classes (all except the macrolides); these isolates were from Québec (Table 4. 36).

Five isolates of 4,[5],12:i:- from Ontario and one isolate of 9,12:-:- from British Columbia were also resistant to 6 antimicrobial classes (all except the macrolides) (Table 4. 36).

Seventy percent (144/207) of *Salmonella* isolates from cattle were resistant to three or more antimicrobial classes; just 28% (58/207) were susceptible to all antimicrobials tested (Table 4. 36).

Chickens

Salmonella (n = 227)

Enteritidis was the most common serovar from chickens (60%, 135/227). All Enteritidis isolates from chickens were susceptible to all of the antimicrobials tested (Table 4. 37).

Kentucky was the second most common serovar from chickens (12%, 28/227). All isolates were resistant to aminoglycosides and tetracyclines and 7 were also resistant to beta-lactams (25%, 7/28) (Table 4. 37).

One Infantis isolate from Québec and 1 Indiana isolate from Ontario were resistant to 5 antimicrobial classes; neither was resistant to macrolides or quinolones (Table 4. 37).

Seventy-eight percent (177/227) of all *Salmonella* isolates from chickens were susceptible to all antimicrobials tested (Table 4. 37).

Pigs

Salmonella (n = 404)

Typhimurium, 4,[5],12:i:-, Derby and Infantis were the most common serovars recovered from clinical pigs in 2016, representing 37% (150/404), 13% (52/404), 12% (48/404) and 9% (35/404) of isolates, respectively (Table 4. 38).

Seventeen isolates from pigs (4%, 17/404) demonstrated resistance to 6 antimicrobial classes; 15 were resistant to all classes except the quinolones and 2 were resistant to all

classes except the macrolides. These included 6 4,[5],12:i:- isolates (all from Ontario), 6 Typhimurium isolates (3 Manitoba, 2 Québec, 1 Ontario), 4 Ohio var. 14+ (3 Manitoba, 1 Ontario), and 1 Infantis (Québec). Different from 2015, quinolone resistance was observed in 2 clinical isolate from pigs (both Typhimurium from Québec) (Table 4. 38). This is the first time that resistance to quinolones has been observed in clinical isolates from pigs since 2013.

Horses

Salmonella (n = 8)

One Typhimurium isolate demonstrated resistance to aminoglycosides, 1 Agona isolate was resistant to tetracyclines, and 1 4,[5], 12:i:- isolate was resistant to β-lactams (Table 4. 39).

Turkeys

Salmonella (n = 62)

Heidelberg and Senftenberg were the most common serovars recovered from clinical turkeys in 2016, representing 16% (10/62) and 13% (8/62) of isolates, respectively (Table 4. 40).

Two isolates (3%, 2/62) were resistant to 4 antimicrobial classes (1 4,[5],12:i:- and 1 Alachua). One Thompson and 1 Senftenberg (2%, 1/62) were resistant to 5 classes. These multi-class resistant isolates were all from British Columbia except the Thompson isolate that was from Québec (Table 4. 40).

No resistance to quinolone antimicrobials was observed in any isolates from turkeys in 2016; 1 isolate (2%, 1/62) (Thompson) was resistant to macrolides (Table 4. 40).

Multiclass resistance

Table 4. 36 Number of antimicrobial classes in resistance patterns of *Salmonella* from cattle, 2016

Serovar	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial											
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
Dublin	76 (36.7)	1		1	31	43	1	69	68	68	68	66		74			72	7	53	75
Typhimurium	62 (30.0)	18	1	1	39	3	4	41	42	3	2	2		43	22		38	5	5	42
4,[5],12:i:-	18 (8.7)	8			5	5	3	10	9					10	9	1	10		4	10
Heidelberg	7 (3.4)	1	2		4		3	4	6	6	6	6		4	3		4			4
Muenster	6 (2.9)				6			4	6					6	6		6			6
Uganda	6 (2.9)	3		3				3						3						3
Less common serovars	32 (15.5)	27	1	2	1	1	1	3	1	1	1	1		4		1	1		1	5
Total	**207 (100)**	**58**	**4**	**7**	**86**	**52**	**12**	**134**	**132**	**78**	**77**	**75**		**144**	**40**	**2**	**131**	**12**	**63**	**145**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

Serovars represented by less than 2% of isolates were classified as “Less common serovars”.

Table 4. 37 Number of antimicrobial classes in resistance patterns of *Salmonella* from chickens, 2016

Serovar	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial											
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
Enteritidis	135 (59.5)	135																		
Kentucky	28 (12.3)			28				28	7	7	7	7								28
Typhimurium	14 (6.2)	10	4					4												
Heidelberg	13 (5.7)	8	2	3			2	3	3	2	2	2		2						
Braenderup	11 (4.8)	10		1			1	1						1						
Infantis	5 (2.2)	4			1		1	1	1	1	1	1		1			1			1
Less common serovars	21 (9.3)	10	6	4	1		3	10	5	2	2	2		2			1			5
Total	**227 (100)**	**177**	**12**	**36**	**2**		**7**	**47**	**16**	**12**	**12**	**12**		**6**			**2**			**34**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

Serovars represented by less than 2% of isolates were classified as “Less common serovars”.

Table 4. 38 Number of antimicrobial classes in resistance patterns of *Salmonella* from pigs, 2016

Serovar	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial											
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
Typhimurium	150 (37.1)	24	5	19	96	6	21	116	104					119	22	4	90	1	2	119
4,[5],12:i:-	52 (12.9)	2	2	4	38	6	12	45	47	2	2	2		48	14	6	14			50
Derby	48 (11.9)		6	26	16		1	41	16	7	7	7		41	4	1	4			48
Infantis	35 (8.7)	31		2	1	1	2	3	3	2	2	2		3	1	1	2			3
Mbandaka var. 14+	19 (4.7)			7	12		3	19	12	3	3	3		15	6		9			19
Brandenburg	18 (4.5)	5	6	7			1	3	6					4	3	1	1			10
Schwarzengrund	10 (2.5)	1	1	7	1			8						6		1				9
Less common serovars	72 (17.8)	29	7	16	16	4	8	32	20	5	5	5		35	15	7	9			39
Total	**404 (100)**	**92**	**27**	**88**	**180**	**17**	**48**	**267**	**208**	**19**	**19**	**19**		**271**	**65**	**21**	**129**	**1**	**2**	**297**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

Serovars represented by less than 2% of isolates were classified as “Less common serovars”.

Table 4. 39 Number of antimicrobial classes in resistance patterns of *Salmonella* from horses, 2016

Serovar	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial											
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
Thompson	2 (25.0)	2																		
Typhimurium	2 (25.0)	1	1					1												
Agona	1 (12.5)		1																	1
Ebrie	1 (12.5)	1																		
4,[5],12:i:-	1 (12.5)		1						1											
Newport	1 (12.5)	1																		
Total	**8 (100)**	**5**	**3**					**1**	**1**											**1**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

Serovars represented by less than 2% of isolates were classified as “Less common serovars”.

Table 4. 40 Number of antimicrobial classes in resistance patterns of *Salmonella* from turkeys, 2016

Serovar	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial											
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
Heidelberg	10 (16.1)		2	8			10	10						8						
Senftenberg	8 (12.9)	1		6	1		7	6	7					1			1			2
Hadar	6 (9.7)			6				6	4											6
Muenchen	6 (9.7)	5		1				1						1						1
Agona	4 (6.5)	1		3			2	2	1		1			3						3
Anatum	4 (6.5)			4				4	4											4
Enteritidis	4 (6.5)	4																		
Rough:g,m:-	4 (6.5)	4																		
Bredeney	2 (3.2)			2			2	2	2	2	2	2		2						
Enftenberg	2 (3.2)	1		1			1	1	1											
Orion var. 15+ 34+	2 (3.2)			2			2	2												2
Less common serovars	10 (16.1)	3		2	3		4	6	4	1				5	1	1				5
Total	**62 (100)**	**19**	**4**	**35**	**4**		**28**	**40**	**23**	**3**	**3**	**2**		**20**	**1**	**1**	**1**			**23**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

Serovars represented by less than 2% of isolates were classified as “Less common serovars”.

Surveillance of Feed and Feed Ingredients

Key findings

Feed and Feed Ingredients

Salmonella (n = 46)

The most common serovar recovered from feed was Senftenberg (44%, 20/46). Two of these isolates (4%, 2/46) were resistant to 4 antimicrobial classes: aminoglycosides, folate pathway inhibitors, phenicols, and tetracyclines. Another 3 Senftenberg isolates (7%, 3/46) were resistant to streptomycin only. Finally, 1 Kentucky isolate (2%, 1/46) was resistant to 2 antimicrobial classes: aminoglycosides and tetracyclines. No other resistant isolates of any serovar were recovered from feed samples in 2016 (Table 4. 41).

Multiclass resistance

Table 4. 41 Number of antimicrobial classes in resistance patterns of *Salmonella* from feed and feed ingredients, 2016

Serovar	Number (%) of isolates	Number of isolates by number of antimicrobial classes in the resistance pattern					Number of isolates resistant by antimicrobial class and antimicrobial											
							Aminoglycosides		β-Lactams					Folate pathway inhibitors		Macrolides	Phenicols	Quinolones		Tetracyclines
		0	1	2–3	4–5	6–7	GEN	STR	AMP	AMC	CRO	FOX	MEM	SSS	SXT	AZM	CHL	CIP	NAL	TET
Senftenberg	20 (43.5)	15	3		2			5						2	2		2			2
Cubana	5 (10.9)	5																		
Infantis	4 (8.7)	4																		
Schwarzengrund	3 (6.5)	3																		
Agona	2 (4.3)	2																		
Rough:b:e,n,x	2 (4.3)	2																		
Livingstone	2 (4.3)	2																		
Mbandaka	2 (4.3)	2																		
Tennessee	2 (4.3)	2																		
Kentucky	1 (2.2)			1				1												1
Liverpool	1 (2.2)	1																		
London	1 (2.2)	1																		
Montevideo	1 (2.2)	1																		
Total	**46 (100)**	**40**	**3**	**1**	**2**			**6**						**2**	**2**		**2**			**3**

Antimicrobial abbreviations are defined in the Appendix.

Red, blue, and black numbers indicate isolates resistant to antimicrobials in Categories I, II, and III of importance to human medicine, respectively.

Chapter 5 Design and methods

Antimicrobial use

Human antimicrobial use monitoring activities within the Public Health Agency of Canada (PHAC) are presented in the Canadian Antimicrobial Resistance Surveillance System (CARSS), Report 2016[76]. Select aspects of IQVIA data (formerly QuintilesIMS) from the CARSS 2016 report are included in the integrated findings of this report (per communication with CARSS).

Quantities of antimicrobials distributed for sale for use in animals

As an estimate of antimicrobials used in animals, data on active ingredients distributed for sale were aggregated and provided to the Public Health Agency of Canada by the Canadian Animal Health Institute (CAHI). CAHI is the trade association representing the companies that manufacture and distribute drugs for administration to food (including fish), sporting, and companion animals in Canada. The association estimates that its members' sales represent over 95% of all sales of licensed animal pharmaceutical products in Canada[77]. CAHI coordinates electronic collection of data from its members. Data collection and analysis are performed by a third party, Impact Vet. The CAHI data include information from 17 companies that manufacture antimicrobials products for use in animals in Canada, and 5 major wholesalers/distributors. The CAHI data on the distribution of antimicrobials for use in animals provide a context to interpret other data on antimicrobial use in animals generated through surveillance or research on farm. They also provide a means to estimate gross temporal changes in antimicrobials used in animals.

The level in the distribution chain that kilograms of active ingredients are reported to CIPARS is at the feed manufacturer/veterinary clinic. Antimicrobial use was assigned to either production animal (inclusive of horses) or companion animal by the manufacturers according to label claim, and in the situation where mixed species was indicated on the label, the manufacturer assigned (estimated) the species as either companion animal or production animal.

These data do not represent actual antimicrobial use in a given year; rather, they reflect the volume of antimicrobials distributed by manufacturers and wholesalers. Distribution values should approximate amounts used, particularly when data from more than one year are included. However, when data from only one year are included, distribution values may vary from amounts actually used because of the time lag between distribution and actual use, as well as stockpiling of antimicrobials at various points in the distribution system. The sales data also do not account for drug wastage due to drug expiry.

The data do not include antimicrobials imported for personal use (own use importation or OUI) under the personal-use provision of the federal Food and Drugs Act and its Regulations, nor do they include imported active pharmaceutical ingredients (API), which are drugs imported in non-dosage form and compounded by a licensed pharmacist or veterinarian. The

[76] Available at: https://www.canada.ca/en/public-health/services/publications/drugs-health-products/canadian-antimicrobial-resistance-surveillance-system-report-2016.html. Accessed March 2017.

[77] Canadian Animal Health Institute – About Us. Available at: http://cahi-icsa.ca/about/. Accessed October 2017.

latest information from an Ipsos/Impact Vet study prepared for CAHI is that the lost opportunity value due to OUI and API was estimated to be 13% of total animal health product sales (personal communication Jean Szkotnicki). The CAHI data do not include prescriptions filled by pharmacists using human labelled drugs for antimicrobials used in companion animals. Hence, the CAHI data underestimate the true volume of antimicrobials used in animals in Canada. Also, the CAHI data do not capture what happens to the drugs after purchase; hence these data cannot provide information the actual antimicrobial use practices, such as dose, duration, reason for use, detailed species-specific information, or extra-label use.

The CAHI data include medicines sold directly to pharmacists that have a focus on dispensing for production medicine. It does not include antimicrobial agents moved from veterinarians to pharmacies and then subsequently dispensed by pharmacies. The latter distribution is captured with the veterinary clinic-level data.

CAHI provides the information in categories, with some antimicrobials not independently reported. This is based on a “3 company accounting rule” established by CAHI to comply with the European Union and the United States’ anti-competition regulations. CAHI added in some cases a “90% rule” to be sure not to infringe the regulations in the United States. These accounting rules can result in changes to the categorization of specific antimicrobials over time. For 2016, the antimicrobials are categorized as per Table 5. 1.

Table 5. 1 Canadian Animal Health Institute's aggregation of data on antimicrobial distributed for sale for use in animals, 2016

Antimicrobial class	Ingredient
Aminoglycosides	Amikacin, apramycin, dihydrostreptomycin, framycetin sulfate, gentamicin, neomycin, spectinomycin, streptomycin
β-Lactams/penicillins	Amoxicillin, ampicillin, cloxicillin, penicillin, sulbactam, clavulanic acid
Cephalosporins	Ceftiofur, cephapirin, cefovecin, cefaclor, cefadroxil
Fluoroquinolones	Ciprofloxacin, danofloxacin, enrofloxacin, marbofloxacin, orbifloxacin, pradofloxacin
Chemical coccidiostats and arsenicals	Amprolium, clopidol, decoquinate, diclazuril, narasin, nicarbazin, pyrimethamine, robenidine, toltrazuril, zoalene
Ionophore coccidiostats	Lasalocid, maduramicin, monensin, salinomycin
Lincosamides	Clindamycin, lincomycin, pirlimycin
Macrolides	Erythromycin, gamithromycin, tilmicosin, tylosin, tulathromycin, tildipirosin, tylvalosin
Other antimicrobials	Avilamycin, bacitracins, bambermycin, chloramphenicol, chlorhexidine gluconate, florfenicol, fusidic acid, nitarsone, nitrofurantoin, nitrofurazone, novobiocin, polymixin, tiamulin, virginiamycin
Tetracyclines	Chlortetracycline, oxytetracycline, tetracycline
Trimethoprim and sulfonamides	Ormetoprim, sulfabenzamide, sulfacetamide, sulfadiazine, sulfadimethoxine, sulfadoxine, sulfaguanidine, sulfamerazine, sulfamethazine, sulfanilamide, sulfaquinoxaline, sulfathiazole, trimethoprim

Temporal figures and data tables for significance testing

As the CAHI data represent census information, there is no testing of statistical differences between years (i.e., the CAHI data are not data derived from samples). Any difference in findings between years should reflect a true difference in the quantities of antimicrobials distributed for sale by the member companies.

Population correction unit

Changes in overall distribution of antimicrobials over time may reflect several things, including: true change in use practices, a change in the numbers or types of animals in the population (requiring antimicrobials), changes in disease prevalence necessitating antimicrobial use, and changes in the types of antimicrobials administered (with different potencies). As one way to adjust the sales data for the changing animal populations over time, a denominator accounting for the number of animals and their standardized weights (animal biomass) was applied. This denominator was based on the methodology currently in use by the European Surveillance of Veterinary Antimicrobial Consumption (ESVAC)[78].

ESVAC adjusts the sales data by a population correction unit (PCU) in which a PCU is a proxy for the animal biomass that is at risk of being treated with antimicrobials. It is a technical measurement only; where 1 PCU = 1 kg of different categories of livestock and slaughtered animals. ESVAC methodology was applied to the greatest extent possible, however population information collected by Statistics Canada and Agriculture and Agri-Food Canada is different in structure somewhat from the data accessed by ESVAC (Eurostat and TRACES), hence direct

[78] European Medicines Agency. European Surveillance of Veterinary Antimicrobial Consumption, 2017—Sales of veterinary antimicrobial agents in 30 European countries in 2015. (EMA/184855/2017). Available at: http://www.ema.europa.eu/docs/en_GB/document_library/Report/2017/10/WC500236750.pdf. Accessed October 2017.

comparisons of PCU's or mg/PCU with ESVAC participating country data should only be made with due caution.

The PCU is calculated by multiplying the numbers of livestock and slaughtered animals in each species/production state by the theoretical (standardized) weight at the most likely time of treatment[79,80].

Equation 5. 1 Formula for PCU calculation

a)

$$\text{PCU (kg)} = \text{number of animals} \times \text{average weight of animal at treatment (kg)}$$

b)

$$\text{mg/PCU} = \frac{\text{antimicrobials distributed (mg)}}{\text{PCU (kg)}}$$

National denominator data regarding the number of livestock and slaughtered animals for 2007 to 2016 were obtained from Statistics Canada, Agriculture and Agri-Food Canada, Fisheries and Oceans Canada, the Canadian Animal Health Institute, and Equestrian Canada (formerly known as Equine Canada) websites. Note, that some websites periodically update their historic data; hence the data are considered as accurate as possible on the date accessed.

In 2016, based on consultation with an industry expert, CIPARS changed the weight of Canadian exported pigs (for feeding) for the PCU_{CANADA}. CIPARS additionally applied the 1 kg weight for poultry imported and exported for the PCU_{ESVAC}, but used the reported Canadian weight categories for the PCU_{CANADA}.

Detailed inclusion and exclusion criteria for the PCU denominator

As per ESVAC, exported animals were added to the PCU, whereas imported animals were subtracted, based on the ESVAC assumption that animals are treated in their country of origin. However, it was noted that in the Canadian context, this would vary depending upon the production stage that is crossing the border.

For the purposes of calculating the PCU, production animal species with the largest populations were included, using the same production classes as ESVAC (for the most part – dependent on the availability of the data), with the notable exception that we additionally included beef cows (not included by ESVAC).

Species currently excluded from our PCU calculations include game animals (e.g., moose), "pocket" companion animals (e.g., hamsters, guinea pigs, pet birds), reptiles, and amphibians.

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[79] European Medicines Agency. European Surveillance of Veterinary Antimicrobial Consumption, 2017—Sales of veterinary antimicrobial agents in 30 European countries in 2015. (EMA/184855/2017). Available at: http://www.ema.europa.eu/docs/en_GB/document_library/Report/2017/10/WC500236750.pdf. Accessed October 2017.

[80] Trends in the sales of veterinary antimicrobial agents in 9 European countries—Reporting period: 2005–2009. European Medicines Agency. European Surveillance of Veterinary Antimicrobial Consumption (ESVAC). Available at: www.ema.europa.eu/docs/en_GB/document_library/Report/2011/09/WC500112309.pdf. Accessed October 2017.

For some production stages, import and export data for poultry are included in a different structure before and after 2009, based on the data available from Statistics Canada. The import and export of poultry for select weight categories were added, which is not included in the ESVAC methodology.

Provincial stratification of the numerator and denominator

There may be subsequent distribution of antimicrobials across provincial borders after being distributed to the veterinary clinics (in particular the movement of medicated feed; for example, anecdotal information was that New Brunswick has a negligible feed-mill industry, they generally purchase their medicated feed from Québec), hence caution should be applied when interpreting the quantities of antimicrobials distributed for sale within each province. Provincial/regional calculations of PCU are pending further discussion.

Overall discussion of strengths and limitations

The CAHI data provides a rough measure of antimicrobials distributed for sale for all animal species, including those not covered by CIPARS farm-level surveillance (with appropriate caveats regarding OUI/API). The PCU metric currently does not take into account the lifespan of the animal, which may affect the interpretation of the quantities of antimicrobials administered to animals. Also, use of a static standard weight may not reflect an industry shift in production affecting the average weights of animals treated, related to weather, trade, or other reasons. Measures of antimicrobial use as reported by broad categories and by a PCU denominator do not account for the amount of the drug needed to achieve therapeutic success. This could affect interpretation of trends. For example, a decrease in the mg/PCU could potentially reflect a switch to using a drug that has smaller daily dose, as opposed to reflecting a decrease in the actual exposure of animals to antimicrobials. The CAHI data should be interpreted as one measure describing antimicrobials used in animals, strong caution should be applied with making inferences to any use practice for a particular animal species.

There have been several advances in detail of these data over the past recent years. Since 2011, the data have been stratified by province, since 2012 stratified by companion animal/production animal, and since 2013 stratified by route of administration.

Quantities of antimicrobials distributed for sale for use on crops

Health Canada's Pest Management Regulatory Agency (PMRA) collects annual Canadian sales data from all pesticide manufacturers. Sales information on antimicrobials registered as pesticides on food crops was kindly provided by PMRA to CIPARS. These data represent antimicrobials administered for the following reasons: fireblight on pome fruits (apples, pears, quince), caneberries and Saskatoon berries; blossom blast and bacterial canker on cherries; stem canker and bacterial spot on greenhouse and field fruiting vegetables (peppers, tomatoes, and eggplant); and walnut blight of walnuts. To protect confidential business information, the data are only presented in this report in combination with data from humans and animals.

Farm surveillance

Farm questionnaire

Broiler chickens

In the broiler chicken Farm Surveillance component of CIPARS, sentinel farm data were collected through questionnaires administered by the poultry veterinarian (or designated practice staff) to the producer (or designated farm staff). The questionnaires collected information related to the hatchery and to the broiler farm. Veterinarians asked the producers for the chick delivery receipts, which contain information required to fill the hatchery-level portion of the questionnaire. Data collected included breeder flock information together with source origin (e.g., province of origin or imported); the age range of the breeder flock whether the hatchery purchased the chicks as hatching eggs or chicks; the antimicrobials used, routes of administration, and the dosage. Additionally the primary reason for antimicrobial use, such as treatment, prevention, high risk flock source, or producer request was captured. Also collected were secondary reasons for use, such as avian pathogenic *E. coli*, *Enterococcus cecorum*, *Salmonella* spp., *Staphylococcus* spp., early clostridial infections and other diseases. Information on vaccines administered in ovo or at the time of hatch were recorded. The veterinarians or designated staff confirmed the information by calling the hatcheries.

The broiler farm portion of the questionnaire was completed by using feed delivery receipts, farm records, prescriptions and/or by asking the producer. Farm demographic information such as quota period, age and estimated weight of birds at the time of visit, farm/barn/floor capacity, as well as biosecurity and animal health information (i.e., vaccines administered at the farm level) were also obtained.

Producers or designated farm personnel were asked about antimicrobial use (AMU) via feed and water. Data were collected on each diet fed to the flock. Information collected on each type of feed included whether the feed contained antimicrobials (medicated feed) or did not contain antimicrobials (non-medicated feed), the total days fed and age of the flocks at the start and end of each ration. Additional information was collected for diets containing antimicrobials including active ingredient(s), their concentration(s) in the feed, and the primary reason(s) for that AMU (growth promotion, disease prevention, or treatment). Secondary AMU reasons were captured if the primary use was for disease prevention or treatment; the list for secondary reasons included the most commonly diagnosed conditions in broilers: yolk sacculitis, septicemia, musculoskeletal diseases, respiratory diseases, necrotic enteritis, coccidiosis, and other diseases (e.g., any non-bacterial etiology such as viral and metabolic).

Data collected on exposure to antimicrobials though water included active ingredient(s) in the drug(s) used, dosage (per liter of drinking water), start and end age of each water medication, the proportion of the flock exposed, and the reason(s) for use. The primary and secondary reasons for prevention and treatment for AMU in water were similar to those described for feed AMU. The producers were also asked if a prescription was provided by a veterinarian and whether the water medication was an over the counter purchase.

Based on the required components of the National Avian On-Farm Biosecurity Standard[81], relevant questions were asked pertaining to the level of biosecurity. Questions on access management, animal health management and operational management were included. Data on flock health status (i.e., diagnosis of the most common bacterial and viral diseases) and vaccine administration from the time of chick placement onwards were also collected.

Grower-finisher pigs

In the grower-finisher's Farm Surveillance component of CIPARS, sentinel farm data were collected through questionnaires administered by the herd veterinarian (or designated staff) to the producer (or designated farm staff). The questionnaires included sections requesting information on AMU, herd demographics and animal health.

Questions pertaining to the number of pigs in the population of interest differed by management system: continuous-flow or all-in-all-out. All-in-all-out management is a production system whereby animals are moved into and out of facilities in distinct groups. By preventing the commingling of groups, the intention is to reduce the spread of diseases. Facilities are normally cleaned and disinfected thoroughly between groups of animals. This type of management is generally all-in-all-out by room or by barn. In continuous-flow operations, animals are continually being added to and removed from the production system.

The AMU questionnaire was designed to collect data for groups of pigs in the grower-finisher production phase. No data on individual pigs were collected. Six pens representative of this population were selected for the collection of fecal specimens for bacterial culture and antimicrobial susceptibility testing. Thus, in herds with all-in-all-out management, the population of interest included all pigs that entered and exited the barn in the same group as the sampled pigs. The population of interest in herds with continuous-flow management was the pigs that entered the grower-finisher unit with the sampled pigs.

Herd owners/managers were asked about AMU via feed, water, and injections. Information collected on each type of feed administered during the grow-finish period included whether the feed contained antimicrobials (medicated feed) or did not contain antimicrobials (non-medicated feed), the average number of weeks each ration was fed and the associated start and end pig weights. Additional information was collected for diets (rations) containing antimicrobials: active antimicrobial ingredient(s), their concentration(s) in the feed, and the primary reason(s) for that AMU (either growth promotion, disease prevention, or treatment). If disease prevention or treatment was selected under the primary reason for AMU, respondents could choose any one of the following secondary reasons for use in feed: respiratory disease, enteric disease, lameness or other diseases. The proportion of pigs fed each diet was also captured.

Data collected on exposure to antimicrobials through water or injection included active ingredient(s) of the drug(s) used, the reason(s) for use and the proportion of pigs exposed. The primary reasons for AMU in water included disease prevention and disease treatment with associated secondary reasons for use being respiratory disease, enteric disease, lameness or other diseases. Only disease treatment reasons were collected for AMU administered by injection. The number of pigs exposed to AMU by water or injection was captured as categorical data with ranges of 1 to 25%, 26 to 50%, 51 to 75% or 76 to 100% of the pigs.

[81] Government of Canada. Animal biosecurity: National avian on-farm biosecurity standard. Available at: www.inspection.gc.ca/DAM/DAM-animals-animaux/STAGING/text-texte/terr_biosec_avian_standard_1375192173847_eng.pdf. Accessed September 2014.

No AMU data were collected for any production phase prior to the grower-finisher phase. Any data regarding AMU in pigs weighing less than 15 kg (33 lb) were excluded because this weight was considered below the industry standard for grower-finisher pigs.

Turkeys

In the turkey Farm Surveillance component of CIPARS, sentinel farm data were collected through questionnaires administered by the poultry veterinarian (or designated practice staff) to the producer (or designated farm staff). Data were collected on the intended market of the birds sampled. The potential markets were; broilers at 5.5 kg average weight and 64 to 71 days of age, light hens at 7.2 kg average weight and 76 to 83 days of age, heavy hens at 9.4 kg average weight and 99 to 106 days of age, light toms at 12.2 kg average weight and 97 to 104 days of age and heavy toms at 15.1 kg average weight and 109 to 116 days of age.

Hatchery drug use was obtained via the poult delivery receipts or by calling the hatcheries (if from domestic source). Data collected included breeder flock information together with source origin (e.g., province of origin or imported); the age range of breeder flock; whether the hatchery purchased the poults as hatching eggs or poults; the antimicrobials used, route of administration, and dosage. Additionally, the primary reason for antimicrobial use such as treatment, prevention, high risk breeder flock source, or producer request was obtained. The targeted bacteria or disease was also recorded: *E. coli*, *Salmonella* spp., *Staphylococcus* spp., or other. The veterinarians or designated staff confirmed the hatchery information by calling the hatcheries.

Farm antimicrobial drug use was completed by using feed delivery receipts, farm records, prescriptions and/or by asking the producer. Farm demographic information, age and estimated weight of birds at the time of visit, farm/barn/floor capacity, as well as biosecurity and animal health information (i.e., vaccines administered at the farm level) were also obtained.

Producers or designated farm personnel were asked about AMU via feed and water. Data were collected on each diet fed to the flock. Information collected on each type of feed included whether the feed contained antimicrobials (medicated feed) or did not contain antimicrobials (non-medicated feed), the total days fed and age of the flocks at the start and end of each ration. Additional information was collected for diets containing antimicrobials: active ingredient(s), their concentration(s) in the feed, and the primary reason(s) for that AMU (growth promotion, disease prevention, or treatment). Secondary AMU reasons were captured if the primary use was for disease prevention or treatment; the list for secondary reasons included the most commonly diagnosed conditions in turkeys: yolk sacculitis, septicemia, musculoskeletal diseases, respiratory diseases, enteric diseases, coccidiosis, and other diseases (e.g., any non-bacterial etiology such as viral and metabolic).

Data collected on exposure to antimicrobials though water included active ingredient(s) in the drug(s) used, dosage (g or mL/L of drinking water), start and end age of each water medication, the proportion of the flock exposed, and the reason(s) for use. The primary and secondary reasons for prevention and treatment for AMU in water were similar to those described for feed AMU. The producers were also asked if a prescription was provided by a veterinarian and whether the water medication was an over-the-counter purchase.

Based on the required components of the National Avian On-Farm Biosecurity Standard[82], relevant questions were asked pertaining to the level of biosecurity. Questions on access management, animal health management and operational management were included. Data on flock health status (i.e., diagnosis of the most common bacterial and viral diseases) and vaccine administration from the time of poult placement onwards were also collected.

Data analysis[83]

Data were entered into a PostGreSQL Database and descriptive statistics were obtained with commercially available software[84].

Broiler chickens

Antimicrobial exposures from the hatching stage to the end of growth or pre-harvest sampling stage (greater than or equal to 30 days) were summarized for each flock. An exposure was defined as any reported use of an active ingredient by a given route of administration. Data were reported as exposure to an active ingredient by a given route of administration, as well as by exposure to an active ingredient by any administration route. These exposures were summarized by antimicrobial active ingredient for frequency table and summed up by class in the quantitative metrics/indicators.

Feed consumption

Estimates of feed intake were based on simple regression and integral calculus. Feed consumption estimates from most recently available performance standards (Ross and Cobb strains) and the performance objectives developed by nutrition companies[85,86,87,88,89] were loaded into Microsoft™ Excel. From these data, the cumulative feed consumption was calculated using the average of feeding standards for the 2 most common broiler strains and the standards developed by feeding companies (i.e., non-strain specific) for as-hatched broilers (i.e., males and females combined). A plot of feed consumption in grams per bird per day was created.

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[82] Government of Canada. Animal biosecurity: National avian on-farm biosecurity standard. Available at: www.inspection.gc.ca/DAM/DAM-animals-animaux/STAGING/text-texte/terr_biosec_avian_standard_1375192173847_eng.pdf. Accessed September 2014.

[83] Please refer to the "Quantity of antimicrobials used in broiler chickens" section for the quantity of antimicrobial use in grower-finisher pigs and turkey calculations.

[84] Microsoft Excel® 2003 and Microsoft Access® 2003, Microsoft Corp., Redmond, WA, USA; SAS® 9.1, SAS Institute Inc., Cary, NC, USA.

[85] Cobb-Vantress, Inc. Products: Cobb 500™. Broiler Performance and Nutrition Supplement. Revised December 2012. Available at: https://cobb-guides.s3.amazonaws.com/a71b8bc0-bbd4-11e6-bd5d-55bb08833e29.pdf. Accessed October 2017.

[86] Cobb-Vantress, Inc. Products: Cobb 700™. Broiler Performance and Nutrition Supplement. Revised July 2015. Available at: http://www.cobb-vantress.com/docs/default-source/cobb-700-guides/cobb700_broiler_performance_nutrition_supplement_english9294AABB12037B70EE475E39.pdf. Accessed September 2016.

[87] Aviagen. Ross 308. Available at: http://en.aviagen.com/assets/Tech_Center/Ross_Broiler/Ross-308-Broiler-PO-2014-EN.pdf. Accessed October 2017.

[88] Aviagen. Ross 708. Available at: http://en.aviagen.com/assets/Tech_Center/Ross_Broiler/Ross-708-Broiler-PO-2014-EN.pdf. Accessed October 2017.

[89] Wallenstein Feeds (Revised March 2016) and Trouw Nutrition, formerly Nutreco Canada Inc. (version received, October, 2016).

From the broiler chicken questionnaire the start and end age of the birds was available for each ration. Since the end day of one ration was the start day of the next an algorithm was used to prevent overlapping days for each subsequent ration. Regression parameters were calculated within Microsoft™ Excel by using the plotted feed intake curve. A minimum R-square value of more than 0.99 was required to be considered a good fit of the regression line. To obtain the best fitting regression line, the broiler chicken feeding curve was divided into 3 segments. Segment 1, or the first regression line, the estimates were utilized to calculate feed consumption if the age of the birds when they started or finished the ration was less or equal to 21 days (i.e., equivalent to brooding and early grow-out period) (Table 5. 2). The second regression line estimates (segment 2) were used if the age of the birds when they started or finished the ration was greater than or equal to 35 days of age (i.e., equivalent to finisher phase or extended grow-out period in roasters) (Table 5. 2). All other age ranges had feed consumption based on the third regression line depicted (i.e., grow-out period) (Table 5. 2).

Feed consumption calculations were then based on the regression coefficients that were calculated and presented in Table 5. 2. For each ration the appropriate regression coefficients (based on start and end age of the birds) and the number of days the ration was fed (as entered in the survey) were substituted into the area under the curve formulas provided (Table 5. 2). For each ration, 2 integrals were calculated. The lower integral set “t” as the ration start age and the upper integral set “t” as the ration end age. The difference between the upper and lower integral yielded the estimate of feed intake in g/bird for that ration. Feed consumption was converted from grams to tonnes and multiplied by the number of birds at risk (i.e., total birds minus half of the mortalities) to provide an estimate of total tonnes fed for each ration. The number of birds reported were the total birds delivered in the poultry unit of concern (barn or floor) including the 2% allowance provided by the hatchery. This value was then utilized to calculate the grams of antimicrobial consumed per ration and incorporated into the quantitative analysis.

Table 5. 2 Regression coefficients and area under the curve formula for broiler feed consumption

Segment of feed curve	Bird age in days	Calculated regression coefficients				R^2	Formula for area under the curve and feed consumption calculation
		β_0	β_1	β_2	β_3		
1	≤ 21	14.096	1.2095	0.228	-0.003	0.99	$\beta_0 t + \beta_1 t^2/2 + \beta_2 t^3/3 + \beta_3 t^4/4$
2	≥ 35	-13.06	4.8777	0.085	-0.0017	0.99	$\beta_0 t + \beta_1 t^2/2 + \beta_2 t^3/3 + \beta_3 t^4/4$
3	All other ages	-27.935	8.827	-0.069	-5.00E-05	0.99	$\beta_0 t + \beta_1 t^2/2 + \beta_2 t^3/3 + \beta_3 t^4/4$

Water consumption

Estimates of water consumption were based on simple regression and integral calculus. Water consumption estimates were uploaded into Microsoft™ Excel. Estimates were based on daily water consumption chart[90] and a plot of intake in L per bird per day was created.

[90] Provided by Trouw Nutrition, formerly Nutreco Canada Inc. (version received October, 2016).

From the broiler chicken questionnaire, the start and end age of the birds was available for each water treatment. An algorithm was used to prevent any possible overlapping of age in days for consecutive water treatments with different antimicrobials in the same flock. Regression parameters were calculated within Microsoft™ Excel by using the plotted water intake curve. A minimum R-square value of greater than 0.99 was required to be considered a good fit of the regression line. To obtain the best fitting regression values, the water consumption curve was divided into 3 segments. If the age of the birds when they started and ended the water treatment was less than or equal to 21 days of age, the water consumption was based on the regression line for segment 1 of the curve (Table 5. 3). If the age of the birds when they started or ended the water treatment was less than or equal to 38 days of age, the water consumption was based on the regression line for segment 2 of the curve (Table 5. 3). All other age ranges had water consumption calculated from the regression line for segment 3 of the curve. From the regression coefficients, the water consumption could then be calculated using integral calculus and the area under the curve formula as described above under broiler chicken feed consumption (Table 5. 3).

Table 5. 3 Regression coefficients and area under the curve formula for broiler chickens water consumption

Segment of water curve	Bird age in days	Calculated regression coefficients				R^2	Formula for area under the curve and water consumption calculation
		β_0	β_1	β_2	β_3		
1	≤ 21	0.0322	8.00E-05	0.0005	-7.00E-06	0.99	$\beta_0 t + \beta_1 t^2/2 + \beta_2 t^3/3 + \beta_3 t^4/4$
2	≥ 38	0.0335	-0.0003	0.0005	-7.00E-06	0.99	$\beta_0 t + \beta_1 t^2/2 + \beta_2 t^3/3 + \beta_3 t^4/4$
3	All other ages	-0.4475	0.0417	-0.0007	4.00E-06	0.99	$\beta_0 t + \beta_1 t^2/2 + \beta_2 t^3/3 + \beta_3 t^4/4$

Quantity of antimicrobials used in broiler chickens

Based on the species-specific calculations above, the milligrams of active ingredient were obtained for each route of administration, reported by route and aggregate of all routes. For Equation 5. 2 to Equation 5. 4, total animals pertains to the starting flock or herd population minus half of the reported mortalities.

Equation 5. 2 Estimation of total milligrams in feed (broiler chickens, pigs, turkeys)

$$\text{mg}_{\text{feed}} = (\text{total animals}) \times \text{feed (kg)} \times \text{level of drug} \left(\frac{\text{mg drug}}{\text{kg feed}}\right)$$

Equation 5. 3 Estimation of total milligrams in water (broiler chickens and turkeys)

$$\text{mg}_{\text{water}} = (\text{total animals}) \times \text{water consumption (L)} \times \text{level of drug} * \left(\frac{\text{mg}}{\text{L}}\right)$$

Level of drug* = Inclusion rate indicated in the label x concentration of the drug.

Equation 5. 4 Estimation of total milligrams via *in ovo* or subcutaneous injections at the hatchery (broiler chickens and turkeys)

$$\text{mg}_{\text{injection}} = (\text{total broilers}) \times \text{mg per hatching egg or chick}$$

Based on the quantity of feed or water consumed, plus quantity administered via injection (for broiler chickens and turkeys only) from the above calculations, the following antimicrobial use metrics or indicators were reported:

Milligrams active ingredient / population correction unit (mg / PCU): Total milligrams (combined injections, feed and water for broilers and turkeys, and feed only for pigs) for each antimicrobial/class and overall, adjusted for animal population (1 grow-out cycle) and weight.

Step 1 population correction unit (PCU) or biomass. (Equation 5. 5): The PCU was calculated by multiplying the total number of animals reported in the questionnaire (equivalent to 1 grow-out cycle; population minus half the mortalities) by the theoretical (standardized) weight at the most likely time of treatment (ESVAC standard weight of 1 kg for broiler, 6.5 kg for turkeys, and 65 kg for swine was used).

Step 2 mg / PCU (Equation 5. 6): Estimation of mg/PCU for each antimicrobial active ingredient, subsequently aggregated by class, and overall to generate year-specific estimate per species.

Equation 5. 5 Formula for PCU calculation

$$\text{PCU (kg)} = \text{number of animals} \times \text{average weight at treatment (kg)}$$

Equation 5. 6 Formula for mg / PCU calculation

$$\text{mg}/\text{PCU} = \frac{\text{antimicrobials in feed (mg)} + \text{water (mg)} + \text{injection (mg)}}{\text{PCU (total population} \times \text{standard weight in kg)}}$$

Canadian Defined Daily Doses using Canadian doses (DDDvetCA): The Canadian average labelled daily doses for each antimicrobial were assigned following similar methodology to ESVAC's DDDvet assignment with some exceptions[91].

Step 1 Average daily dose (Equation 5. 7): The average daily dose was determined as follows: each antimicrobial was assigned a DDDvetCA by obtaining all approved doses for pigs and chickens (prevention and

[91] European Medicines Agency, 2016: Defined daily doses for animals (DDDvet) and defined course doses for animals (DCDvet). European Surveillance of Veterinary Antimicrobial Consumption (ESVAC). Accessed on January 2017.

treatment purposes) from 2 Canadian references[92,93] or from expert opinion, where no labelled product existed (extra-label drug use, ELDU)[94]. The sum of all the doses was then divided by the total number of unique doses.

Step 2 DDDvetCA (Equation 5. 8): Because the labelled dose (inclusion rates) varied by pharmaceutical form (e.g., g/tonne for products administered via feed, g/L water for products administered via the drinking water, mg/chick or hatching eggs for injectable products), values were standardized in mg_{drug}/kg_{animal}/day based on the ESVAC approach. As in the ESVAC methodology[95], for combination products, DDDvetCA for each antimicrobial component was determined. In broiler chickens and turkeys, this applies to the combination drugs lincomycin-spectinomycin and trimethoprim-sulfadiazine. The values for pigs and chickens are summarized in Table A. 3 and Table A. 4. Please note that metric development is an iterative process, and thus these values may change (e.g., new products available, change in product labels or approved claims, refinement of the metric).

Equation 5. 7 Average daily dose calculation

$$\text{Average daily dose} = \frac{\sum_{(\text{all unique doses})} \text{a}}{\text{Number of unique doses from Canadian references}}$$

[a] All unique doses indicated for treatment and prevention were used to calculate the average daily dose of an antimicrobial; an antimicrobial may have more than one unique dose by product format and/or indication.

Equation 5. 8 Standardization of average daily dose to obtain DDDvetCA with units in mg of drug per kilogram of body weight (animal) per day

$$\text{DDDvetCA} = \text{average daily dose} \times \text{conversion factor}^{\text{a}}$$

[a] A conversion factor is used to standardize the DDDvetCA unit in mg_{drug}/kg_{animal}/day as in the ESVAC approach; please refer to Table A. 5 and Table A. 6 for broiler chicken/turkey and grower-finisher pig-specific conversion factors, respectively.

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[92] CFIA, 2016b: Compendium of Medicating Ingredient Brochure. Available at: http://www.inspection.gc.ca/animals/feeds/medicating-ingredients/eng/1300212600464/1320602461227. Accessed on January 2017.

[93] Canadian Animal Health Institute, 2016: Compendium of Veterinary Products. Available at: https://bam.naccvp.com/?u=country&p=msds. Accessed on January 2017.

[94] Canadian Association of Poultry Veterinarians. Available at: http://www.capv-acva.ca/BroilerChicken.htm. Accessed on January 2017.

[95] European Medicines Agency, 2016. European Surveillance of Veterinary Antimicrobial Consumption. Defined daily doses for animals (DDDvet) and defined course doses for animals (DCDvet) (ESVAC). Available at: http://www.ema.europa.eu/docs/en_GB/document_library/Other/2016/04/WC500205410.pdf. Accessed January 2017.

The nDDDvetCA (Equation 5. 9): For each antimicrobial active ingredient and aggregate of all the antimicrobial active ingredients (yearly total) are adjusted by various species-specific technical units of measurement (e.g., population, weight, days at risk) as described in Equation 5. 9 and Equation 5. 10. Similar to mg/PCU, these indicators are also used for between antimicrobial class and inter-species comparisons over time.

Equation 5. 9 Calculating the number of daily doses in animals using Canadian standards (nDDDvetCA)

$$\text{nDDDvetCA} = \frac{\text{total milligrams}^{a}}{\text{DDDvetCA standard in mg/kg/day}}$$

[a] This is the numerator, combining milligrams consumed via feed (broilers and turkeys), water and injections.

Number of Canadian Defined Daily Doses (nDDDvetCA) / 1,000 animal-days at risk (Equation 5. 10): Also known as treatment incidence and there are many variations of this equation[96,97,98,99]. This indicator was calculated by dividing the nDDDvetCA (Equation 5. 9) values to the denominator value (flock or herd population minus half of the mortalities multiplied by the ESVAC standard weight and the mean number of days each for one production cycle for the monitored flocks or herds). The days at risk is year-specific (e.g., 2016: 34 days for broiler chickens, 114 days for grower-finisher pigs, and 90 days for turkeys). The final step multiplied the values to 1,000. Please note that Equation 5. 10 differed slightly from the 2015 CIPARS Annual Report; the calculation below was modified to reflect the sequential steps leading to the final antimicrobial use indicator and in line with the methodology described in the literature.

Equation 5. 10 Formula for the number of DDDvetCA / 1,000 animal-days at risk

$$\text{nDDDvetCA}/_{\text{1,000 animal–days at risk}} = \left(\frac{\text{total antimicrobials (mg)}/\text{DDDvetCA}_{\text{mg/kg/day}}}{\text{total animals} \times \text{ESVAC std. weight (kg)} \times \text{days at risk}}\right) \times 1{,}000$$

Std. = standard.

[96] Persoons D, Dewulf J, Smet A, Herman L, Heyndrickx M, Martel A, et al. Antimicrobial use in Belgian broiler production. Prev Vet Med. 2012.

[97] Timmerman T, Dewulf J, Catry B, Feyen B, Opsomer G, de Kruif A, Maes D. 2006. Quantification and evaluation of antimicrobial drug use in group treatments for fattening pigs in Belgium. Prev. et Med. 74:251-263.

[98] Collineau L, Belloc C, Stärk KD, Hémonic A, Postma M, Dewulf J, Chauvin C. 2017. Guidance on the Selection of Appropriate Indicators for Quantification of Antimicrobial Usage in Humans and Animals. Zoonoses Public Health. 64:165-184.

[99] The AACTING-network. Guidelines for collection, analysis and reporting of farm-level antimicrobial use, in the scope of antimicrobial stewardship. Available at: http://www.aacting.org/guidelines/. Accessed on March 2018.

Number of Canadian Defined Daily Doses/population correction unit (nDDDvet/PCU) (Equation 5. 11): This metric adjusted the nDDDvetCA to the species-specific biomass (see Equation 5. 8, step 2) based on a method described elsewhere[100].

Equation 5. 11 Formula for the number of DDDvetCA/PCU

$$\text{nDDDvetCA}/_{\text{PCU}} = \frac{\text{total antimicrobials (mg)}/\text{DDDvetCA}_{\text{mg/kg/day}}}{\text{total animals} \times \text{ESVAC std. weight}}$$

Std. = standard.

Grower-finisher pigs

Antimicrobial exposures were summarized for each herd. An exposure was defined as any reported use of an active ingredient by a given route of administration in 2016. Data were reported as exposure to an active ingredient by a given route of administration, as well as by exposure to an active ingredient by any administration route. These exposures were summarized by antimicrobial class. It is important to note that antimicrobial exposures through feed tend to involve larger groups of pigs and longer durations of use than antimicrobial exposures via water. Injectable antimicrobials are generally administered on an individual basis to a limited number of pigs[101].

Feed consumption

Quantitative AMU data (dose and duration) were collected for antimicrobials administered through feed but not for antimicrobials administered through water or by injection. The amount of an antimicrobial consumed through feed was estimated from the concentration of the antimicrobial in a given ration multiplied by the cumulative tonnes consumed over the duration of exposure. Estimates of feed intake were based on simple regression equations and integral calculus. Plots of feed consumption per day were created within Microsoft™ Excel, using National Research Council (NRC) tables (Nutrient Requirements of Swine: Eleventh Revised Edition, National Academy of Sciences, 2012) for grower-finisher pigs. Three plots were created to reflect poor (15% less protein deposition per kg feed consumed than the standard pig), medium (standard pig described by NRC), and high (15% more protein deposition than the standard pig) performance. The lightest starting weight recorded for all rations listed on a questionnaire was selected and the corresponding day on the feed consumption table was identified. The number of days the ration was fed was then added to the start day to obtain an end day for that ration. For each successive ration, the number of days the ration was fed was added to the proceeding ration end day. When the reported

[100] European Centre for Disease Prevention and Control (ECDC), European Food Safety Authority (EFSA) and European Medicines Agency (EMA). Second joint report on the integrated analysis of the consumption of antimicrobial agents and occurrence of antimicrobial resistance in bacteria from humans and food-producing animals—Joint Interagency Antimicrobial Consumption and Resistance Analysis (JIACRA) Report. Available at: http://www.ema.europa.eu/docs/en_GB/document_library/Report/2017/07/WC500232336.pdf. Accessed on October 2017.

[101] Version April, 2009. Available at: www.hc-sc.gc.ca/dhp-mps/vet/antimicrob/amr_ram_hum-med-rev-eng.php. Accessed February 2017.

feeding end day went beyond the NRC table, data were extrapolated up to maximum of 50 additional days.

Regression parameters for each level of pig performance were calculated within Microsoft™ Excel by using the feed intake curve (Table 5. 4). A minimum R-square value higher than 0.99 was required to be considered a good fit of the regression line. From the regression coefficients the feed consumption could then be calculated using integral calculus and the area under the curve formula provided in Table 5. 4 similar to that described above under broiler feed consumption. However, for swine, 3 regression lines (poor, medium and higher performance) were created per ration. Two integrals were calculated using the formula in Table 5. 4. For the lower integral "t" is the start age of the pigs on the ration and for the upper integral "t" is the end age of the pigs on the ration. The difference between the upper and lower integral yielded the estimate of feed intake in kilograms per pig for that ration. For each grower-finisher pig herd an average daily gain (ADG) was calculated based on data provided in the questionnaire; starting and ending weights as well as the number of days pigs were in the grower-finisher stage of production. Farms were categorized as having poor, medium, or high performance by using cut off points which were generated by partitioning the questionnaire ADG data into thirds. High performance herds were defined as herds with an ADG more than 0.8734, medium performance herds had an ADG between 0.8734 to 0.8045, and poor performance herds had ADG less than 0.8045. Based on this categorization, the appropriate regression line and integral were applied to calculate feed consumption. Feed consumption was converted from kilograms to tonnes and multiplied by the number of pigs at risk to provide an estimate of total tonnes fed for each ration. This value was then utilized to calculate the grams of antimicrobial consumed per ration and incorporated in quantitative analyses.

Table 5. 4 Regression coefficients and area under the curve formula for grower-finisher pig feed consumption

Pig performance	Calculated regression coefficients			R^2	Formula for area under the curve and feed consumption calculation
	β_0	β_1	β_2		
Poor	0.901	0.0243	-7.00E-05	0.99	$\beta_0 t + \beta_1 t^2/2 + \beta_2 t^3/3$
Medium	0.8974	0.0267	-9.00E-05	0.99	$\beta_0 t + \beta_1 t^2/2 + \beta_2 t^3/3$
High	0.8945	0.0291	-0.0001	0.99	$\beta_0 t + \beta_1 t^2/2 + \beta_2 t^3/3$

Quantity of antimicrobials used in grower-finisher pigs

Please refer to the "Quantity of antimicrobials used in broiler chickens" section (see above) for the quantity of antimicrobial use in grower-finisher pigs calculations.

Turkeys

Antimicrobial exposures from the hatching stage to the end of growth or pre-harvest sampling stage (approximately 1 week prior to slaughter) were summarized for each flock. An exposure was defined as any reported use of an active ingredient by a given route of administration. Data were reported as exposure to an active ingredient by a given route of administration, as well as by exposure to an active ingredient by any administration route. These exposures were summarized by antimicrobial class.

Feed consumption

Estimates of feed intake were based on simple regression and integral calculus. Feed consumption estimates from most recently available references including performance standards for Aviagen (Nicolas)[102] and Hybrid turkeys[103] were loaded into Microsoft™ Excel. From these data, the cumulative feed consumption was calculated using the average of feeding standards for the 2 most common broiler strains and the standards developed by feeding companies (i.e., non-strain specific) for as-hatched broilers. Regression calculations were completed for broiler turkeys, turkey hens and Tom turkeys

Feed consumption was calculated on a per ration bases using the same methodology as described above for broiler chicken feed consumption. Separate regression coefficients were calculated for broiler turkeys, hens and toms and were applied appropriately based on the selection of the target market from the survey at the time of data entry. Regression line coefficients and area under the curve formulas are provided in Table 5. 5.

Table 5. 5 Regression coefficients and area under the curve formula for turkey feed consumption

Bird type	Calculated regression coefficients				R^2	Formula for area under the curve and feed consumption calculation
	β_0	β_1	β_2	β_3		
Broiler turkeys	-0.1085	0.1782	0.008	-0.0003	0.99	$\beta_0 t + \beta_1 t^2/2 + \beta_2 t^3/3 + \beta_3 t^4/4$
Toms	-0.0545	0.1398	0.016	-0.0005	0.99	$\beta_0 t + \beta_1 t^2/2 + \beta_2 t^3/3 + \beta_3 t^4/4$
Hens	-0.1424	0.2016	0.002	-0.0002	0.99	$\beta_0 t + \beta_1 t^2/2 + \beta_2 t^3/3 + \beta_3 t^4/4$

[102] Nicolas Performance Objectives. Available at: http://www.aviagenturkeys.us/uploads/2015/12/21/nicholas_comm_perf_obj_select_2015.pdf. Accessed on October 2017.

[103] Hybrid turkeys performance goals. Available at: http://resources.hybridturkeys.com/commercial/birds. Accessed on October 2017.

Water consumption

Estimates of water consumption were based on simple regression and integral calculus. Water consumption estimates were uploaded into Microsoft™ Excel from most recently available reference[104] and a daily water consumption chart and a plot of intake in liters/bird/day was created.

Water consumption was calculated on a per treatment course basis using the same methodology as described above for broiler chicken water consumption. Separate regression lines were calculated for birds less than or equal to 13 weeks of age and for those greater than 13 weeks of age to achieve the best fitting curve. Regression line coefficients and area under the curve formulas are provided in Table 5. 6.

Table 5. 6 Regression coefficients and area under the curve formula for turkey water consumption

Segment of water curve	Bird age in weeks	Calculated regression coefficients			R^2	Formula for area under the curve and water consumption calculation
		β_0	β_1	β_2		
1	≤ 13	-0.0131	0.0487	0.0019	0.99	$\beta_0 t + \beta_1 t^2/2 + \beta_2 t^3/3$
2	> 13	0.8922	0.0018	0.0002	0.99	$\beta_0 t + \beta_1 t^2/2 + \beta_2 t^3/3$

Quantity of antimicrobials used in turkeys

Please refer to the “Quantity of antimicrobials used in broiler chickens” section (see above) for the quantity of antimicrobial use in turkey calculations.

[104] Available at: http://www.aviagenturkeys.us/uploads/2015/12/21/Aviagen%20Breeder%20Guide%202015.pdf. Accessed October, 2017.

Antimicrobial resistance

Human surveillance

Objective(s)

The objective of the Surveillance of Human Clinical Isolates component of CIPARS is to provide a representative and methodologically unified approach to monitor temporal variation in the prevalence of antimicrobial resistance in *Salmonella* isolated from humans.

Surveillance design

Hospital-based and private clinical laboratories culture human *Salmonella* isolates in Canada. Although reporting is mandatory through laboratory notification of reportable diseases to the National Notifiable Disease Reporting System, forwarding of *Salmonella* isolates to provincial reference laboratories is voluntary and passive. A high proportion (84% in 2001)[105] of *Salmonella* isolates are forwarded to Provincial Public Health Laboratories (PPHLs), but this proportion may vary among laboratories. The Yukon, Northwest Territories, and Nunavut, which do not have a PPHL counterpart, forwarded their isolates to one of the PPHLs.

Prior to 2002, PPHLs forwarded *Salmonella* isolates to the Enteric Diseases Program, National Microbiology Laboratory (NML)@Winnipeg, Public Health Agency of Canada (PHAC), Winnipeg, Manitoba for confirmation and subtype characterization. A letter of agreement by which provinces agreed to forward all or a subset of their *Salmonella* isolates to NML@Winnipeg for CIPARS was signed in 2002 by the PPHLs and PHAC. This agreement officially launched the surveillance program.

To ensure a statistically valid sampling plan, all human *Salmonella* isolates (outbreak-associated and non-outbreak-associated) received passively by PPHLs in Saskatchewan, Manitoba, New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland and Labrador were forwarded to the NML. The PPHLs in more heavily populated provinces (British Columbia, Alberta, Ontario, and Québec) forwarded only the isolates received from the 1st to the 15th of each month. However, all human *S*. Newport and *S*. Typhi isolates were forwarded to the NML because of concerns of multidrug resistance and clinical importance, respectively.

The PPHLs were also asked to provide a defined set of data for each forwarded isolate, including serovar name, date collected, and patient age, sex, and province of residence.

[105] Report of the 2001 Canadian Laboratory Study, National Studies on Acute Gastrointestinal Illness, Division of Enteric, Foodborne and Waterborne Diseases, 2002.

Retail meat surveillance

Objective(s)

The objectives of CIPARS Retail Meat Surveillance component are to provide data on the prevalence of antimicrobial resistance and to monitor temporal variations in selected bacteria found in raw meat at the province/region level.

Surveillance design

Retail Meat Surveillance provides a measure of human exposure to antimicrobial-resistant bacteria via the consumption of undercooked meat. Retail food represents a logical sampling point for surveillance of antimicrobial resistance because it is the endpoint of food animal production. Through meat sample collection and testing, the retail surveillance component provides a measure of human exposure to antimicrobial resistant bacteria through the consumption of meat products available for purchase by Canadian consumers. The scope of the surveillance framework can be modified as necessary (e.g., to evaluate different food commodities, bacteria, or geographic regions) and functions as a research platform for investigation of specific questions regarding antimicrobial resistance in the agri-food sector.

The unit of concern in Retail Meat Surveillance in 2016 was the bacterial isolate cultured from one of the commodities of interest. In this situation, the commodities were raw meat products commonly consumed by Canadians, which originated from the 3 animal species sampled in the Abattoir Surveillance component as well as turkey beginning in 2012. These raw meat products consisted of chicken (legs or wings [skin on]), turkey (ground), pork (chops), and beef (ground).

For ground beef, a systematic collection of extra-lean, lean, medium, and regular ground beef was performed to ensure representation of the heterogeneity of ground beef with respect to its origins (e.g., domestic vs. imported beef or raised beef cattle vs. culled dairy cattle). The meat cuts “legs or wings with skin on”, “ground turkey”, “pork chops”, and “ground beef” were chosen on the basis of suspected high prevalences of the targeted bacterial species within and the low purchase prices of these commodities[106] and for comparability to other international retail surveillance programs .

Bacteria of interest in chicken were *Campylobacter, Salmonella*, and generic *E. coli* and *Salmonella* and generic *E. coli* only for ground turkey. Recovery of *Campylobacter* from ground turkey was stopped mid-2016 due low prevalence and to free-up additional laboratory capacity. In pork, both *Salmonella* and *E. coli* were cultured, but only isolates of *E. coli* underwent antimicrobial susceptibility testing for routine surveillance and annual reporting. *Salmonella* was isolated from pork mainly to provide recovery estimates from this commodity for other Public Health Agency of Canada programs. Because the prevalence of *Salmonella* in pork is low, antimicrobial susceptibility results are not presented on an annual basis but are pooled and presented over a multi-year period in the interest of precision. Recovery of *Campylobacter* from pork was not attempted because of the low prevalence observed in the initial stages of Retail Meat Surveillance. In beef, only *E. coli* was cultured and then tested for antimicrobial susceptibility given the low prevalence of *Campylobacter* and *Salmonella* in this commodity at the retail level, as determined during the early phase of the program.

[106] Ravel A. Antimicrobial Surveillance in food at retail – Proposal for a pilot project. 2002. 13 pp.

Sampling methods

Generally, the sampling protocol was designed to evaluate antimicrobial resistance in certain bacterial species that contaminate retail meat and to which Canadian consumers may subsequently be exposed. In 2016, it primarily involved continuous weekly submission of samples of retail meat from randomly selected geographic areas (i.e., census divisions defined by Statistics Canada), weighted by population, in each participating province.

In 2016, retail meat samples were collected in British Columbia, Prairies (a region including the provinces of Saskatchewan, Alberta, and Manitoba[107]), Ontario, and Québec. Unlike previous years (2013 and 2014), no data were presented in recent years (2015 and 2016) for the Atlantic region (a region including the provinces of New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland and Labrador[108]) as retail sampling activities in this region were suspended due to budgetary constraints. Additionally, during the 2016 sampling year in Ontario, only a partial year's worth of retail sampling was conducted due to the availability of sampling technician staff. As a result, the sampling target and subsequent isolate yields in this province were not achieved and therefore, all retail data presented for Ontario in 2016 should be interpreted with caution.

Data from Statistics Canada were used to define strata. This was done by using cumulative population quartiles (or tertiles from a list of census divisions in a province, sorted by population in ascending order. Generally, between 15 and 18 census divisions per province/region were then chosen by means of stratified random selection and weighted by population within each stratum. The number of sampling days allocated to each stratum was also weighted by population and is summarized as follows:

British Columbia

- Stratum 1: 10 divisions selected, with 1 sampling day per division per year
- Stratum 2: 4 divisions selected, with 3 sampling days per division per year
- Stratum 3: 1 division selected, with 20 sampling days per year

Prairies (Alberta only for 2016)

- Stratum 1: 9 divisions selected, with 2 sampling days per division per year
- Stratum 2: 5 divisions selected, with 3 sampling days per division per year
- Stratum 3: 2 divisions selected, with 5 sampling days per division per year
- Stratum 4: 1 division selected, with 7 sampling days per year

Ontario and Québec

- Stratum 1: 10 divisions selected, with 2 sampling days per division per year
- Stratum 2: 4 divisions selected, with 5 sampling days per division per year
- Stratum 3: 2 divisions selected, with 10 sampling days per division per year
- Stratum 4: 1 division selected, with 20 sampling days per year

[107] No retail sampling was conducted in Manitoba to-date or Saskatchewan in 2016.

[108] No retail sampling was conducted in Newfoundland and Labrador.

Generally, field workers in Ontario[109] and Québec conducted sampling on a weekly basis, and those in British Columbia and the Prairie region conducted sampling every other week. Sampling was less frequent in British Columbia and the Prairie region because of funding constraints, limited laboratory capacity, and a desire to avoid over-sampling at particular stores. Samples were collected on Mondays or Tuesdays for submission to the laboratory by Wednesday. Samples submitted from outside Québec were sent to the same laboratory via 24-hour courier.

In each province in most cases, 2 census divisions were sampled each sampling week. In each census division, 4 stores were selected prior to the sampling day, based on store type. Generally, 3 chain stores and 1 independent market or butcher shop were selected. An exception to this protocol was made in densely populated urban census divisions (e.g., Toronto or Montréal), where 2 chain stores and 2 independent markets or butcher shops were sampled to reflect the presumed shopping behaviour of that subpopulation. Generally speaking, from each store type, 1 sample of each commodity of interest was attempted, for a desired total of 15 meat samples (4 chicken, 4 turkey, 4 pork, and 3 beef samples) per division per sampling day[110]. When possible, specific stores were sampled only once per sampling year. In some cases due to reduced availability of certain meats and store closures etc., the desired sample yield was not achieved.

Prevalence estimates were used to determine the numbers of samples to be collected, which were based on an expected yield of 100 isolates per commodity per province per year, plus 20% to account for lost or damaged samples. Because sampling was less frequent in British Columbia and the Prairie region than in Ontario[111] and Québec, the target of 100 isolates per year may not have always been met in those provinces/regions.

Notebook computers containing a custom electronic submission form were used to capture the following store and sample data:

- Type of store
- Number of cash registers (surrogate measure of store volume)
- “Sell-by” or packaging date
- “May contain previously frozen meat” label: yes or no
- Final processing in store: yes, no, or unknown
- Air chilled: yes, no, or unknown (applied to chicken samples only)
- Organic: yes, no, or unknown
- Antimicrobial free: yes, no, or unknown
- Price per kilogram

[109] For 2016, due to limited sampling technician availability, only a partial year’s worth of retail sampling was conducted in Ontario and the Prairies. Sampling target and isolate yields were therefore not achieved. All 2016 Ontario and Prairie retail data should be interpreted with caution. Additionally in 2016, retail sampling activities in the Atlantic region were suspended due to budgetary constraints.

[110] At 1 store in each division (except the Atlantic region), the beef sample was not collected to minimize over-sampling of this commodity.

[111] For 2016, due to limited sampling technician availability, only a partial year’s worth of retail sampling was conducted in Ontario and the Prairies. Sampling target and isolate yields were therefore not achieved. All 2016 Ontario and Prairie retail data should be interpreted with caution. Additionally in 2016, retail sampling activities in the Atlantic region were suspended due to budgetary constraints.

Individual samples were packaged in sealed zipper-type bags and placed in 16 L thermal coolers for transport. The ambient environmental temperature was used to determine the number of ice packs placed in each cooler (i.e., 1 ice pack for temperatures below 20°C and 2 ice packs for temperatures 20°C or higher). In 1 or 2 coolers per sampling day, instruments for recording temperature data[112] were used to monitor temperatures to which samples were exposed.

Abattoir surveillance

Objective(s)

The objectives of the CIPARS Abattoir Surveillance component are to provide nationally representative, annual antimicrobial resistance data for bacteria isolated from animals entering the food chain, and to monitor temporal variations in the prevalence of antimicrobial resistance in these bacteria.

Surveillance design

Abattoir Surveillance only includes animals that originated from premises within Canada. Established in September 2002, this component initially targeted generic *Escherichia coli* and *Salmonella* within the food animal commodities associated with the highest per capita meat consumption: beef cattle, broiler chickens, and pigs. In 2003, the component was refined to discontinue *Salmonella* isolation from beef cattle because of the low prevalence of *Salmonella* in that population. *Campylobacter* surveillance was initiated in beef cattle in late 2005 in order to include a pathogen in beef cattle surveillance and to provide data on fluoroquinolone resistance, following the approval of a fluoroquinolone for use in cattle. *Campylobacter* surveillance was also initiated in chickens in 2010 and pigs in 2012.

In the Abattoir Surveillance component, the unit of concern (i.e., the subject of interest) was the bacterial isolate. The bacteria of interest were isolated from the caecal contents (not carcasses) of slaughtered food animals to avoid misinterpretation related to cross-contamination and to better reflect antimicrobial resistance in bacteria that originated on the farm.

Over 90% of all food-producing animals in Canada are slaughtered in federally inspected abattoirs annually[113]. The program is based on the voluntary participation of federally inspected slaughter plants from across Canada. The sampling method was designed with the goal that, across Canada, 150 isolates of *Salmonella* and generic *E. coli* and 100 isolates of *Campylobacter* would be recovered from each of the 3 animal species over a 12 month period. These numbers represented a balance between acceptable statistical precision and affordability[114]. The actual number of samples collected was determined for each food animal species on the basis of the expected caecal prevalence of the bacteria in that animal species.

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[112] Ertco Data Logger™, West Patterson, NJ, USA.

[113] Agriculture and Agri-Food Canada. Red meat market information. Available at http://www5.agr.gc.ca/eng/industry-markets-and-trade/market-information-by-sector/red-meat-and-livestock/red-meat-and-livestock-market-information/slaughter. Accessed October 2017.

[114] Ravel A. Development of the Canadian antimicrobial resistance surveillance system (agri-food sector)–sampling design options. Presented to the National Steering Committee on Antimicrobial Resistance in Enterics, Canada, 2001. 79 pp.

For example, if the goal was 150 isolates and the expected bacterial prevalence was 10%, then 1,500 samples would need to be collected and submitted for bacterial isolation.

The sampling design was based on a 2-stage sampling plan, with each commodity handled separately. The first stage consisted of random selection of federally inspected slaughterhouses. The probability of an abattoir being selected was proportional to its annual slaughter volume. The second stage involved systematic selection of animals on the slaughter line. The annual number of caecal samples collected at each abattoir was proportional to its slaughter volume.

Sampling methods

To minimize shipping costs and allow each abattoir to maintain efficiency, the annual total number of samples to be collected in each abattoir was divided by 5, resulting in the number of collection periods. For each collection period, 5 to 7 caecal samples were collected within 5 days, at the convenience of the slaughterhouse staff, provided the 5 animals and associated samples originated from different groups. Sampling from different groups of animals was important to maximize diversity and avoid bias attributable to overrepresentation of particular producers. Collection periods were uniformly distributed throughout the year to avoid any bias that may have resulted from seasonal variation in bacterial prevalence and antimicrobial susceptibility test results.

Forty-five federally inspected slaughter plants (5 beef cattle plants, 27 poultry plants, and 13 swine plants) from across Canada participated in the 2016 CIPARS Abattoir Surveillance component. These plants represented over 95% of the cattle, 70% of the chickens, and 80% of the pigs slaughtered at federally inspected abattoirs in Canada in 2016. Samples were obtained according to a predetermined protocol, with modifications to accommodate various production-line configurations in the different plants. Protocols were designed to avoid conflict with carcass inspection methods, plant-specific Food Safety Enhancement Programs, and Health and Safety requirements. They were also designed to avoid situations of potential cross-contamination. All samples were collected by industry personnel under the oversight of the Veterinarian-in-Charge of the Canadian Food Inspection Agency.

Farm surveillance

Objective(s)

The objectives of the CIPARS Farm Surveillance component are to provide data on antimicrobial use and resistance, to monitor temporal trends in the prevalence of antimicrobial resistance, to investigate associations between antimicrobial use and resistance on grower-finisher pigs, and broiler chickens, and to provide data for human health risk assessments.

Surveillance design

The Farm Surveillance component was the third active surveillance component implemented by CIPARS. Taken together, with the Abattoir Surveillance and Retail Meat Surveillance components, these data validate the information collected at key points along the farm-to-fork food production chain. This initiative is built on a sentinel farm framework. Questionnaires are used to collect data on farm demographics, animal health and antimicrobial use. Composite pen fecal samples are collected and submitted to laboratories for bacterial isolation and antimicrobial susceptibility testing. The bacteria of interest in broiler chickens, feedlot

beef, and turkeys were *Campylobacter*, *Salmonella*, and generic *E. coli*; *Salmonella* and generic *E. coli* were isolated in grower-finisher pigs.

Feedlot beef

The CIPARS Farm Surveillance feedlot beef component was initiated in 2016. Sampling is currently only being done in the Alberta FoodNet Canada site, however, expansion into a nation program is the long term objective. This stage of production was selected because of their proximity to the consumer.

Broiler chickens

The CIPARS Farm Surveillance broiler chicken component was initiated in April 2013 in the 4 major poultry-producing provinces in Canada (British Columbia, Alberta, Ontario, and Québec). In 2014, due to external funding from Saskatchewan Agriculture, Saskatchewan also started to participated in the program. The Broiler Farm Surveillance component samples flocks at least 1 week before shipment for slaughter (i.e., pre-harvest stage). This stage of production was selected because it is most proximal to the consumer of all the farm production stages. Half of the flocks sampled for the year were also sampled at the time of chick placement to determine the resistance profiles of chicks on arrival and carry-over of resistant organism from the previous flock.

Grower-finisher pigs

CIPARS Farm Surveillance swine component was initiated in 2006 in the 5 major pork-producing provinces in Canada (Alberta, Saskatchewan, Manitoba, Ontario, and Québec). The swine industry was selected as the pilot commodity for development of the Farm Surveillance infrastructure because the Canadian Quality Assurance (CQA®) program had been extensively implemented by the industry and because, in 2006, unlike in the other major livestock commodities, there had not been a recent outbreak of foreign animal disease in pigs. The Farm Surveillance component concentrates on grower-finisher pigs. Pigs in this stage of production were chosen because of their proximity to the consumer.

Turkeys

The CIPARS Farm Surveillance turkey component was initiated in 2016 in the 3 major poultry-producing provinces in Canada (British Columbia, Ontario, and Québec). The turkey Farm Surveillance component samples flocks at least 1 week before shipment for slaughter (i.e., pre-harvest stage). This stage of production was selected because it is most proximal to the consumer of all the farm production stages.

Sampling methods

Feedlot beef

Feedlot veterinarians, with feedlots in the FoodNet Canada (FNC) Alberta Sentinel site, were purposively selected from the list of veterinarians practicing feedlot medicine. Enrolled veterinarians then recruited sentinel herds to participate in this voluntary surveillance program. Enrolled feedlots were to be representative of the veterinary practice profile. The number of sentinel herds targeted for sampling is 30; which is the required number for the FNC sentinel site. To preserve the anonymity of participating producers, herd veterinarians

collected the samples and data and submit coded information to the Public Health Agency of Canada.

Feedlots were visited once per year for sample and data collection. Pooled fecal samples were collected from 6 pens of cattle that were close to market weight (ideally greater than 120 days on feed and greater than 500 kg). Veterinarians were asked to distribute their sampling visits across the year to account for seasonal variations in pathogen prevalence and diseases that may drive AMU on farms.

A 1 page survey sheet was included with each sampling kit in order to collect information for both FNC and CIPARS. Data requested for each pen of cattle sampled included minimum and maximum days on feed, minimum and maximum weight of cattle in the pen, the average pen capacity, the feedlot capacity, and current inventory. Other information requested, for FNC purposes, related to water source, and water treatments.

Broiler chickens

Poultry veterinarians recruited sentinel flocks to participate in this voluntary national surveillance program. The number of sentinel flocks allocated to each of the 4 participating province/regions (British Columbia, Prairies [Alberta and Saskatchewan], Ontario and Québec) was proportional to the national total of quota-holding producers, except in the FoodNet Canada sentinel sites, where a minimum of 30 flocks were sampled. In Alberta, laboratory testing for all flocks was provided by the Alberta Agriculture and Forestry, Agri-Food Laboratories Branch. In Saskatchewan, the Saskatchewan Ministry of Agriculture provided full financial support for 9 flocks.

To preserve the anonymity of participating producers, poultry veterinarians collected the samples and data and submitted coded information to Public Health Agency of Canada (PHAC). The Canadian Hatchery Federation (CHF) and the Canadian Poultry and Egg Processors Council ensured confidentiality by holding the key to hatcheries; only the coded information was known to PHAC.

Poultry veterinary practices were purposively selected from each province. Each veterinarian recruited a predetermined number of sentinel farm sites proportional to their practice profile and availability by use of specific inclusion and exclusion criteria. To be included, farms were required to be a Safe, Safer, Safest™ compliant quota-holding broiler operations (i.e., broilers are the major commodity reared on-site but producers may also have other animal species and/or commodities). Antibiotic-free, raised without antibiotics or organic production systems were selected proportional to the veterinarian's practice profile. Veterinarians also ensured that selected farms were also representative of all the CHF hatcheries supplying chicks and representative of the feed mills supplying feeds in the province of their practice, and were geographically distributed (i.e., not neighboring flocks). Additionally, these farms were demographically reflective of the veterinary practice and overall broiler industry profile (e.g., variety of flock management: poor to excellent performing flocks, variety in volume of chicks placed: low to high flock densities). These criteria helped ensure that the flocks enrolled were representative of most broiler flocks raised in Canada. The veterinarians were also asked to distribute their sampling visits across the year to account for seasonal variations in pathogen prevalence and diseases that may drive AMU at the hatchery and on farms.

Sentinel broiler flocks were visited during the last week of growth (chickens more than 30 days of age), once per year for sample and data collection. Four pooled fecal samples, representing 1 per floor quadrant with at least 10 fecal droppings were collected from

randomly selected barns and floors (if multiple level/pen barn). On a trial basis, a proportion of the flocks were also visited when the chicks arrived at the barn. Using a sterile sponge, 2 environmental barn surface samples and 3 meconium samples were collected. The meconium samples were collected from the liners (chick pads) of the boxes used to ship chicks from the hatchery to the barn.

Grower-finisher pigs

Swine veterinarians recruited sentinel herds to participate in this voluntary national surveillance program. The number of sentinel herds allocated to each of the 5 participating provinces was proportional to the national total of grower-finisher pig units, except in Saskatchewan, where 3 additional sentinel herds were included. Support for the 3 extra herds, was provided by the Saskatchewan Ministry of Agriculture.

To preserve the anonymity of participating producers, herd veterinarians collected the samples and data and submitted coded information to the PHAC. In the case of corporate herds, noncorporate supervisory veterinarians ensured confidentiality by holding the key to corporate herd codes. This step was taken because knowing a corporate veterinarian's name could have identified the corporation associated with the herd, thereby breaking anonymity.

Veterinarians were purposively selected from the list of veterinarians practicing swine medicine in each province. Each veterinarian selected a predetermined number of sentinel farm sites by use of specific inclusion and exclusion criteria. To be included, herds were required to be CQA® validated, produce more than 2,000 market pigs per year, and be representative of the characteristics (i.e., similar production volumes and types of production systems) and geographic distribution of herds in the veterinarian's swine practice. Herds were excluded when they were regarded as organic with respect to animal husbandry, were fed edible residual material, or were raised on pasture. These criteria helped ensure that the herds enrolled were representative of most grower-finisher pig herds in Canada.

Sentinel grower-finisher pig herds were visited once per year for sample and data collection. Pooled fecal samples were collected from 6 pens of pigs that were close to market weight (i.e., more than 80 kg [175 lb]). Veterinarians were asked to distribute their sampling visits across the year to account for seasonal variations in pathogen prevalence and diseases that may drive AMU on farms.

Turkeys

Poultry veterinarians recruited sentinel flocks to participate in this voluntary national surveillance program. The number of sentinel flocks allocated to each of the 3 participating province/regions (British Columbia, Ontario and Québec) was proportional to the national total of quota-holding producers, except in the FoodNet Canada sentinel sites, where a minimum of 30 flocks were sampled.

To preserve the anonymity of participating producers, poultry veterinarians collected the samples and data and submitted coded information to Public Health Agency of Canada (PHAC). The Canadian Hatchery Federation (CHF) and the Canadian Poultry and Egg Processors Council ensured confidentiality by holding the key to hatcheries; only the coded information was known to PHAC.

Poultry veterinary practices were purposively selected from each province. Each veterinarian recruited a predetermined number of sentinel farm sites proportional to their practice profile

and availability by use of specific inclusion and exclusion criteria. To be included, farms were required to be a TFC On-Farm Food Safety Program© compliant, quota-holding broiler operations (i.e., turkeys are the major commodity reared on-site but producers may also have other animal species and/or commodities). Antibiotic-free, raised without antibiotics or organic production systems were selected proportional to the veterinarian's practice profile. Veterinarians also ensured that selected farms were also representative of all the CHF hatcheries supplying poults and representative of the feed mills supplying feeds in the province of their practice, and were geographically distributed (i.e., not neighboring flocks). Additionally, these farms were demographically reflective of the veterinary practice and overall turkey industry profile (e.g., variety of flock management: poor to excellent performing flocks, variety in volume of poults placed: low to high flock densities). These criteria helped ensure that the flocks enrolled were representative of most turkey flocks raised in Canada. The veterinarians were also asked to distribute their sampling visits across the year to account for seasonal variations in pathogen prevalence and diseases that may drive AMU at the hatchery and on farms.

Sentinel turkey flocks were visited during the last week of growth, depending on the marketing/weight categories (broilers, light hens, heavy hens, light toms, and heavy toms), once per year for sample and data collection. Four pooled fecal samples, representing 1 per floor quadrant with at least 10 fecal droppings were collected from randomly selected barns and floors (if multiple level/pen barn).

Surveillance of animal clinical isolates

Objective(s)

The objective of Surveillance of Animal Clinical Isolates is to detect emerging antimicrobial resistance patterns as well as new serovar/resistance pattern combinations in *Salmonella*.

Surveillance design

This component of CIPARS relies on samples that are typically collected and submitted to veterinary diagnostic laboratories by veterinarians and/or producers. Consequently, sample collection and submission, as well as *Salmonella* isolation techniques varied among laboratories over the year.

Salmonella isolates were sent by provincial and private animal health laboratories from across the country to the *Salmonella* Reference Laboratory (SRL) at the National Microbiology Laboratory (NML)@Guelph with the exception of Québec, where isolates from animal health laboratories were sent to the Laboratoire d'épidémiosurveillance animale du Québec, du ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec for serotyping. Isolates and serotyping results for *S*. Enteritidis and *S*. Typhimurium from Québec were then forwarded to the NML@Guelph for phage typing and antimicrobial resistance testing. Isolates from Québec that were not *S*. Enteritidis or *S*. Typhimurium were serotyped at NML@Guelph. It is important to note that not all isolates received by provincial animal health laboratories were forwarded to the NML@Guelph, with the exception of isolates received by provincial animal health laboratories in British Columbia, Ontario, Québec, and Prince Edward Island. Therefore, coverage may have varied considerably among provinces.

Samples submitted for testing may have been collected from sick animals, animal feed, the animal's environment, or non-diseased animals from the same herd or flock. Results from

chicken, turkey, cattle, pigs, and horses are reported. Cattle isolates could have originated from dairy cattle, milk-fed or grain-fed veal, or beef cattle. Chicken isolates were largely from layer hens or broiler chickens, but could also have been from primary layer breeders or broiler breeder birds. A proportion of the turkey isolates might have been recovered from turkey-related environmental samples.

Feed and feed ingredients

Sampling design

Data from the Feed and Feed Ingredients component of CIPARS were obtained from monitoring programs of the Canadian Food Inspection Agency (CFIA) and a few isolates from provincial authorities.

The CFIA collects samples of animal feed under 2 different programs: Program 15A (Monitoring Inspection: *Salmonella*) and Program 15E (Directed Inspection: *Salmonella*). Under Program 15A, feeds produced at feed mills, rendering facilities, ingredient manufacturers, and on-farm facilities are sampled and tested for *Salmonella*. Although this program makes use of a random sampling process, extra attention is paid to feeds that are more likely to have a higher degree of *Salmonella* contamination, such as those that contain rendered animal products, oilseed meals, fish meals, grains, and mashes. Program 15E targets feeds or ingredients from establishments that:

- produce rendered animal products, other feeds containing ingredients in which *Salmonella* could be a concern (e.g., oilseed meal or fishmeal), or a significant volume of poultry feed.
- are known to have repeated problems with *Salmonella* contamination.
- have identified a *Salmonella* serovar that is highly pathogenic (e.g., Typhimurium, Enteritidis, or Newport).

Program 15E is a targeted program; samples are not randomly selected.

Bacterial isolation methods

All samples were cultured by use of standard protocols as described below. All primary isolation of human *Salmonella* isolates was conducted by hospital-based or private clinical laboratories in participating provinces/regions. Most primary isolation of *Escherichia coli*, *Salmonella*, and *Campylobacter* from agri-food samples was conducted at the National Microbiology Laboratory (NML)@Saint-Hyacinthe. Part of the primary isolation for Farm Surveillance was conducted at the Agri-Food Laboratory of the Alberta Agriculture and Rural Development. Samples from the CIPARS Surveillance of Animal Clinical Isolates component were cultured by various participating laboratories. Most primary bacterial isolation of samples from Feed and Feed Ingredients was conducted by the CFIA: Laboratory Services Division (Calgary or Ottawa).

Salmonella

Surveillance of Human Clinical Isolates

Hospital-based and private clinical laboratories isolated and identified *Salmonella* from human samples according to approved methods[115,116,117,118].

Surveillance of agri-food isolates (Retail Meat Surveillance, Abattoir Surveillance, and Farm Surveillance)

The method used to isolate *Salmonella* was a modification of the MFLP-75 method[119]. This method allowed isolation of viable and motile *Salmonella* from fecal (Farm Surveillance) matter, caecal (Abattoir Surveillance) content, and meat (Retail Meat Surveillance) from agri-food samples. It is based on the ability of *Salmonella* to multiply and be motile in modified semi-solid Rappaport Vassiliadis (MSRV) medium at 42°C.

Retail Meat Surveillance: depending on the sample type either 1 chicken leg[120], 1 pork chop or 25 g of ground turkey was added to 225 mL of Buffered Peptone Water (BPW). One hundred milliliters of the peptone rinse were kept for *Campylobacter* and/or *E. coli* isolation. Chicken and turkey samples were left in the remaining volume of peptone rinse and incubated at 35 ± 1°C for 24 hours. Afterward, a MSRV plate was inoculated with 0.1 mL of the rinse and incubated at 42 ± 1°C for 24 to 72 hours. Migration greater than or equal to 20mm were then streaked onto MacConkey agar. Suspect colonies were screened for purity and used to inoculate triple-sugar-iron and urea agar slants. Presumptive *Salmonella* isolates were assessed using the indole test, and their identities were verified by means of slide agglutination with *Salmonella* Poly A-I and Vi antiserum.

Abattoir Surveillance and Farm Surveillance: a 25 g portion of each beef, pig, broiler chicken, or turkey caecal/fecal sample were mixed with 225 mL of BPW. Chicken caecal/fecal contents were weighed and mixed with BPW at a ratio of 1:10. Environmental and chick meconium sponges were mixed with 100 mL of BPW. Samples were incubated at 35 ± 1°C for 24 hours. Afterward, the method used was the same as the one described in the *Salmonella* Retail Meat Surveillance section.

Surveillance of animal clinical isolates

Salmonella was isolated according to standard procedures, which varied among laboratories. Most methods for detecting *Salmonella* in animal clinical isolates were similar in principle and involved pre-enrichment, selective enrichment, differential and selective plating, isolation, and biochemical and serological confirmation of the selected isolates.

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[115] Kauffman F. The Bacteriology of Enterobacteriaceae. Baltimore: Williams and Wilkins Co, 1966.

[116] Ewing WH. Edwards and Ewing's Identification of Enterobacteriaceae. 4th ed. New York: Elsevier Science Publishing Co, 1986.

[117] Le Minor L. Guidelines for the preparation of *Salmonella* antisera. Paris, France: WHO Collaborating Centre for Reference and Research on Salmonella, Pasteur Institute, 2001.

[118] Murray PR, Baron EJ, Pfaller MA, et al, eds. Manual of Clinical Microbiology. 8th ed. Washington DC, ASM Press, 2005.

[119] Compendium of Analytical Methods, Health Protection Branch, Methods of Microbiological Analysis of Food, Government of Canada.

[120] When legs with skin on were not available, wings with skin on or other cuts were purchased instead.

Feed and feed ingredients

Under both Canadian Food Inspection Agency programs (15A and 15E), all samples were collected aseptically and submitted for bacterial culture and isolation. For *Salmonella* isolation, MSRV medium was used.

Escherichia coli

Retail Meat Surveillance

Fifty milliliters of the peptone rinse prepared as stated in the *Salmonella* Retail Meat Surveillance section were mixed with 50 mL of double strength EC Broth and incubated at 42 ± 1°C for 24 hours. One loopful of the mixture was then streaked onto Eosin Methylene Blue agar and incubated at 35 ± 1°C for 24 hours. Suspect colonies were screened for purity and transferred onto trypticase soy agar with 5% sheep blood. Presumptive *E. coli* colonies were assessed using Simmons citrate and indole tests. The *E. coli* isolates with negative indole test results were confirmed using a bacterial identification test kit[121].

Abattoir Surveillance and Farm Surveillance

One drop of the peptone mixture prepared as earlier stated in the Surveillance of Agri-Food Isolates/*Salmonella* Abattoir Surveillance and Farm Surveillance section was streaked onto MacConkey agar and incubated at 35 ± 1°C for 18 to 24 hours. Suspect lactose-fermenting colonies were screened for purity and transferred onto Luria-Bertani agar. Presumptive *E. coli* colonies were assessed as in the Retail Meat Surveillance for *E. coli*.

Campylobacter

Retail Meat Surveillance

Fifty milliliters of the peptone rinse prepared as previously stated in the *Salmonella* Retail Meat Surveillance section, were mixed with 50 mL of double-strength Bolton broth and incubated in a microaerophilic atmosphere at 42 ± 1°C for 44 to 48 hours. A swab saturated with broth was then swabbed then streaked using 3 quadrants onto a modified Charcoal Cefoperazone Deoxycholate Agar (mCCDA) plate and incubated in a microaerophilic atmosphere at 42 ± 1°C for 24 to 72 hours. Suspect colonies were streaked onto a second mCCDA and incubated. From the second mCCDA plate, a colony was then streaked onto a Mueller Hinton with citrated sheep's blood agar plate and incubated in a microaerophilic atmosphere at 42 ± 1°C for 24 to 48 hours. Presumptive *Campylobacter* colonies were identified using the following tests: Gram stain, oxidase, and catalase. A multiplex PCR (mPCR)[122] was used to speciate colonies. Specific genomic targets (hippuricase in *C. jejuni* and aspartokinase in *C. coli*) were amplified by mPCR from bacterial lysates. Products were visualized on agarose gel and identified based on their specific molecular size using the

[121] API® 20E system.

[122] The multiplex PCR speciation of *Campylobacter jejuni* and *Campylobacter coli* was based on the following published method. Person S, KE Olsen. Multiplex PCR for identification of *Campylobacter coli* and *Campylobacter jejuni* from pure cultures and directly on stool samples. J Med Microbiol 2005; 54:1043–1047.

QIAxcel® method[123]. An internal universal control (16s rRNA) was incorporated into the PCR method. The priming oligonucleotides used in the PCR were highly specific for *C. jejuni* or *C. coli* and will not amplify DNA present in any other *Campylobacter* spp. or non-*Campylobacter* organisms. Unidentified species of *Campylobacter* are collectively referred to in the CIPARS reports as "*Campylobacter* spp.". However, when used alone, the term "*Campylobacter*" refers to all *Campylobacter* species.

Abattoir Surveillance and Farm Surveillance

One milliliter of BPW mixture prepared as previously stated in the *Salmonella* Abattoir Surveillance and Farm Surveillance sections, was mixed with 9 mL of Hunt's enrichment broth (HEB) and incubated in a microaerophilic atmosphere at 35 ± 1°C for 4 hours. After this first incubation, 36 µL of sterile cefoperazone were added to the HEB tubes which were then sent back to microaerophilic incubation, this time at 42 ± 1°C for 20 to 24 hours. A swab saturated with HEB was then used to inoculate a mCCDA plate and incubated at 42 ± 1°C in microaerophilic conditions for 24 to 72 hours. Suspect colonies were assessed as described earlier in the *Campylobacter* Retail Meat Surveillance section.

Serotyping and phage typing methods

Salmonella

Surveillance of Human Clinical Isolates

In general, clinical laboratories forwarded their *Salmonella* isolates to their Provincial Public Health Laboratory (PPHL) for identification and serotyping. The PPHL further forwarded *Salmonella* isolates to the National Microbiology Laboratory (NML)@Winnipeg according to the predefined testing protocol. Isolate identities were confirmed by the NML@Winnipeg when isolates received did not have a serovar name[124] or when inconclusive results arose during phage typing. The O or somatic antigens of the *Salmonella* isolates were serotyped by use of a slide agglutination method[125]. At the NML@Winnipeg, *Salmonella* H or flagellar antigens were detected via slide and confirmatory tube agglutination methods. *Salmonella* isolates were maintained at room temperature between 25° and 35°C until typed.

Phage typing was performed at the NML@Winnipeg for isolates of the following *Salmonella* serovars: Enteritidis, Heidelberg, Typhimurium, Hadar, Newport, Typhi, Paratyphi B[126], Paratyphi B var. L(+) tartrate (+), Infantis, Thompson, Oranienburg, Panama, 4,[5],12:b:-, and

[123] Qiagen®. QIAxcel® DNA Handbook, 5th Edition November 2014. Available at: https://www.qiagen.com/ca/resources/resourcedetail?id=f6158498-a857-4a2f-b40b-569fba3793e2&lang=en. Accessed on October 2016.

[124] Grimont PAD, Weill F-X. Antigenic formulae of the *Salmonella* serovars. 9th ed. Paris, France: WHO Collaborating Centre for Reference and Research on *Salmonella*, Institut Pasteur, 2007.

[125] Ewing WH. Edwards and Ewing's Identification of Enterobacteriaceae. 4th ed. New York: Elsevier Science Publishing Co, 1986.

[126] *Salmonella* Paratyphi B does not include *S*. Paratyphi B var. L (+) tartrate (+), formerly called *S*. Paratyphi var. Java. The biotype of *S*. Paratyphi B included here is tartrate (-) and associated with severe typhoid-like fever. *Salmonella* Paratyphi B var. L (+) tartrate (+) is commonly associated with gastrointestinal illness.

4,[5],12:i:-. For phage typing the standard technique described by Anderson and Williams[127] was followed. Isolates were streaked onto nutrient agar plates and incubated at 37°C for 18 hours. Three to 5 smooth colonies were selected and used to inoculate 4.5 mL of phage broth[128], which was then incubated for 1.5 to 2 hours in a shaking water bath at 37°C to attain bacterial growth with a turbidity equivalent to 1 McFarland standard. Phage agar plates[129] were flooded with approximately 2 mL of culture medium, and the excess liquid was removed with a Pasteur pipette. Flooded plates were allowed to dry for 15 minutes at room temperature. Afterward, approximately 10 μL of each serovar-specific typing phage was used to inoculate the bacterial lawn by means of a multiple inoculating syringe method[130]. The plates were incubated at 37°C overnight, and lytic patterns were subsequently interpreted[131].

Salmonella Enteritidis strains were phage typed with typing phages obtained from the International Centre for Enteric Phage Typing (ICEPT), Central Public Health Laboratory, Colindale, United Kingdom[132]. The phage-typing protocol and phages for *S.* Typhimurium, developed by Callow[133] and further extended by Anderson[134] and Anderson and colleagues[135] were obtained from the ICEPT. The *S.* Heidelberg phage typing protocol and phages were supplied by the NML@Winnipeg[136]. Isolates that reacted with the phages but did not conform to any recognized phage type were designated as atypical. Strains that did not react with any of the typing phages were designated as "untypable".

The Identification and Serotyping unit and the Phage Typing unit at the NML@Winnipeg have attained International Standards Organization (ISO) 17025 accreditation by the Standards Council of Canada. These identification and Serotyping, Phage Typing, and Antimicrobial Resistance units participate in the annual Global Food-borne Infections Network (WHO-GFN), External Quality Assurance System of the World Health Organization, the Enter-net (a European network for the surveillance of human gastrointestinal infections) proficiency program for *Salmonella*, and a strain exchange with the NML@Guelph and NML@Saint-Hyacinthe (*Salmonella* and *Escherichia coli*). The NML@Winnipeg and the Centre for Foodborne, Environmental and Zoonotic Infectious Diseases have been strategic planning members of the WHO-GFN program since 2002.

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[127] Anderson E, Williams R. Bacteriophage typing of enteric pathogens and staphylococci and its use in epidemiology. J Clin Pathol 1956; 9: 94–127.

[128] Difco™ phage broth, Difco Laboratories, Baltimore, MD; pH 6.8.

[129] Difco™ phage agar, Difco Laboratories.

[130] Farmer J, Hickman F, Sikes J. Automation of *Salmonella* typhi phage-typing. Lancet 1975; 2(7939): 787–790.

[131] Anderson E, Williams R. Bacteriophage typing of enteric pathogens and staphylococci and its use in epidemiology. J Clin Pathol 1956; 9: 94–127.

[132] Ward L, de Sa J, Rowe B. A phage-typing scheme for *Salmonella* Enteritidis. Epidemiol Infect 1987; 99: 291–294.

[133] Callow B. A new phage typing scheme for *Salmonella* Typhimurium. J Hyg (Lond) 1959; 57: 346–359.

[134] Anderson E. The phagetyping of *Salmonella* other than *S.* Typhi. In: Van Oye E, ed. The World Problem of Salmonellosis. The Hague, The Netherlands: Dr W. Junk Publishers, 1964; 89–100.

[135] Anderson E, Ward L, de Saxe M, et al. Bacteriophage-typing designations of *Salmonella* Typhimurium. J Hyg (Lond) 1977; 78: 297–300.

[136] Demczuk W, Soule G, Clark C, et al. Phage-based typing scheme for *Salmonella* enterica serovar Heidelberg, a causative agent of food poisonings in Canada. J Clin Microbiol 2003; 41: 4279–4284.

Surveillance of agri-food, animal clinical and feed isolates

Animal clinical *Salmonella* isolates from Québec were serotyped at the Laboratoire d'épidémiosurveillance animale du Québec, du ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec and were sent to the OIE *Salmonella* Reference Laboratory (SRL) NML@Guelph[137] (previously known as Laboratory for Foodborne Zoonoses). *Salmonella* isolates of serovars Enteritidis, Heidelberg, and Typhimurium were not re-serotyped, they were only phage typed. All other *Salmonella* isolates sent to SRL by MAPAQ were serotyped. *S.* Heidelberg isolates were also phage typed. All other *Salmonella* isolates tested as part of CIPARS, including clinical isolates from other provinces, were submitted to the SRL for serotyping and phage typing.

Serotyping of CIPARS isolates was carried out using either the traditional phenotypic serotyping method or a DNA microarray-based alternative method called the *Salmonella* GenoSerotyping Array (SGSA)[138]. The phenotypic serotyping method detects O or somatic antigens of the *Salmonella* isolates via slide agglutination[139]. The H or flagellar antigens were identified with a microtitre plate well precipitation method[140]. The antigenic formulae and serovars of the *Salmonella* isolates were identified and designated as per White-Kauffmann-Le Minor (WKL) scheme[141]. The SGSA detects the genes encoding surface O and H antigens and reports the corresponding *Salmonella* serovar in accordance with the existing WKL serotyping scheme.

For phage typing, the standard technique by Anderson and Williams[142] and described above was followed. Phage typing was performed on isolates of *Salmonella* serovars Enteritidis, Typhimurium, and Heidelberg; the sources of the typing phages for these 3 serovars were the same as described above for Surveillance of Human Clinical Isolates.

The SRL is ISO 17025 accredited by the Standards Council of Canada. The SRL participates in the annual inter-laboratory exchange of serotyping panels with up to 3 other laboratories and External Quality Assurance System of the World Health Organization proficiency program. Every year, the SRL participates in phage typing proficiency panels from the NML@Winnipeg.

Antimicrobial susceptibility testing methods

All *Salmonella* isolates of human origin were tested for antimicrobial susceptibility at the National Microbiology Laboratory (NML)@Winnipeg and all *Salmonella* isolates of agri-food or feed origin were tested for antimicrobial susceptibility at the NML@Guelph. The majority of *Campylobacter* and *Escherichia coli* isolates from all agri-food components were tested at the NML@Saint-Hyacinthe. One isolate per positive sample was submitted for antimicrobial susceptibility testing.

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[137] Office Internationale des Épizooties (OIÉ); World Organisation for Animal Health, Reference Laboratory for Salmonellosis, Guelph, Ontario.

[138] Yoshida C., et al. Multi-laboratory evaluation of the rapid genoserotyping array (SGSA) for the identification of Salmonella serovars. Diag Microbiol & Infect Dis 2014; 80:185-190.

[139] Ewing WH. Edwards and Ewing's Identification of Enterobacteriaceae. 4th ed. New York: Elsevier Science Publishing Co, 1986.

[140] Shipp C, Rowe B. A mechanised microtechnique for *Salmonella* serotyping. J Clin Pathol 1980; 33: 595–597.

[141] Grimont PAD, Weill F-X. Antigenic Formulae of the Salmonella Serovars. 9th ed. Cedex, France: Collaborating Center for Reference and Research on *Salmonella*, Institut Pasteur, 2007.

[142] Anderson E, Williams R. Bacteriophage typing of enteric pathogens and staphylococci and its use in epidemiology. J Clin Pathol 1956; 9: 94–127.

The NML@Winnipeg is a World Health Organization Collaboration Centre for Preparedness and Response to Enteric Pathogens and their Antimicrobial Resistance. The NML@Guelph and NML@Saint-Hyacinthe laboratories participate in external proficiency programs for antimicrobial susceptibility testing for *Salmonella* and *Campylobacter*. The NML@Saint-Hyacinthe laboratory participate in inter-agency proficiency programs for identification and antimicrobial susceptibility testing of *Salmonella, E. coli*, and *Campylobacter* with the National Antimicrobial Resistance Monitoring System, United States (NARMS). The NML@Guelph laboratory and NML@Saint-Hyacinthe are ISO/IEC 17025-accredited for antimicrobial susceptibility testing.

Salmonella and *Escherichia coli*

The minimum inhibitory concentration (MIC) values for *Salmonella* and *E. coli* were determined by use of an automated broth microdilution method[143,144]. This automated incubation and reading system uses microtitre plates containing various concentrations of dehydrated antimicrobials. The CMV4AGNF plate[145] was designed by the NARMS and contains 14 antimicrobials (see Table 5. 7, Antimicrobial Susceptibility Breakpoints' section).

Isolates were streaked onto a Mueller Hinton plate and incubated at 35 ± 1°C for 18 to 20 hours to obtain isolated colonies. One colony was chosen from the plate and re-streaked onto Mueller Hinton agar plates (NML@Guelph uses MacConkey agar for *E. coli*) for growth. The plates were incubated at 35 ± 1°C for 18 to 20 hours. A 0.5-McFarland suspension was prepared by transferring bacterial growth from the agar plates into 5.0 mL of sterile, demineralized water. Ten microliters of the water-bacteria suspension were transferred to 11 mL of Mueller Hinton broth (MHB). This suspension was dispensed onto CMV4AGNF testing plates at 50 µL per well and the plates were sealed with adhesive plastic sheets. After 18-hours of incubation at 35 ± 1°C the plates were read automatically with the fluorometric plate reading system[146]. In accordance with standards set by the Clinical and Laboratory Standards Institute (CLSI)[147], *Staphylococcus aureus* ATCC 29213, *Escherichia coli* ATCC 25922, *Pseudomonas aeruginosa* ATCC 27853, and *Enterococcus faecalis* ATCC 29212 were used for quality assurance purposes to ensure validity of the MIC values.

Campylobacter

The MIC values for *Campylobacter* were determined by means of the broth microdilution method[148]. The CAMPY plates designed by NARMS and containing 9 dehydrated antimicrobials were used (see Table 5. 8, Antimicrobial Susceptibility Breakpoints'section). Colonies were streaked onto Mueller Hinton agar plates with 5% sheep blood and incubated in a microaerophilic atmosphere at 42 ± 1°C for 24 hours. A 0.5-McFarland suspension of bacterial growth was prepared by transferring selected bacterial colonies into a tube containing 5 mL of MHB. Afterward, 100 µL of the MHB were transferred to 11 mL of MHB with laked horse

[143] Clinical and Laboratory Standards Institute (CLSI) M7-A10.

[144] Sensititre™ Trek Diagnostic Systems Ltd, West Sussex, England.

[145] Sensititre™ Trek Diagnostic Systems Ltd, West Sussex, England.

[146] ARIS™, Trek™ Diagnostic Systems Ltd, West Sussex, England.

[147] CLSI M100-S26.

[148] CLSI M45-ED-3.

blood. The mixture was dispensed onto CAMPY plates at 100 µL per well. The plates were sealed with perforated adhesive plastic sheets. After a 24-hour incubation in microaerophilic atmosphere at 42 ± 1°C, plates were read using the Sensititre Vizion System[149]. *Campylobacter jejuni* ATCC 33560 was used as quality control organism. The MIC values obtained were compared with those of CLSI standards[150].

Antimicrobial susceptibility breakpoints

Table 5. 7 Antimicrobial susceptibility breakpoints for *Salmonella* and *Escherichia coli*; CMV4AGNF plate, 2016

	Antimicrobial	Range tested (µg/mL)	Breakpoints[a] (µg/mL)		
			S	I	R
I	Amoxicillin-clavulanic acid	1.0/0.5–32/16	≤ 8/4	16/8	≥ 32/16
	Ceftriaxone	0.25–64	≤ 1	2	≥ 4
	Ciprofloxacin	0.015–4	≤ 0.06	0.12–0.5	≥ 1
	Meropenem	0.06–4	≤ 1	2	≥ 4
II	Ampicillin	1–32	≤ 8	16	≥ 32
	Azithromycin[b]	0.25–32	≤ 16	N/A	≥ 32
	Cefoxitin	0.5–32	≤ 8	16	≥ 32
	Gentamicin	0.25–16	≤ 4	8	≥ 16
	Nalidixic acid	0.5–32	≤ 16	N/A	≥ 32
	Streptomycin[b]	2–64	≤ 16	N/A	≥ 32
	Trimethoprim-sulfamethoxazole	0.12/2.38–4/76	≤ 2/38	N/A	≥ 4/76
III	Chloramphenicol	2–32	≤ 8	16	≥ 32
	Sulfisoxazole	16–256	≤ 256	N/A	≥ 512
	Tetracycline	4–32	≤ 4	8	≥ 16
IV					

Roman numerals I to IV indicate the ranking of antimicrobials based on importance in human medicine as outlined by the Veterinary Drugs Directorate.

S = susceptible. I = intermediate susceptibility. R = resistant. N/A = not applicable.

[a] Unless otherwise specified, CLSI M100-S26 was the reference used for all antimicrobials in the panel.

[b] No Clinical and Laboratory Standards Institute interpretive criteria for Enterobacteriaceae were available for this antimicrobial. Breakpoints were based on the distribution of minimal inhibitory concentrations and were harmonized with those of the National Antimicrobial Resistance Monitoring System, United States.

[149] Sensititre™ Trek Diagnostic Systems Ltd, West Sussex, England.

[150] CLSI M45-A3.

Table 5. 8 Antimicrobial susceptibility breakpoints for *Campylobacter*; CAMPY plate, 2016

	Antimicrobial	Range tested (µg/mL)	Breakpoints[a] (µg/mL)		
			S	I	R
I	Ciprofloxacin	0.015–64	≤ 1	2	≥ 4
	Telithromycin[b]	0.015–8	≤ 4	8	≥ 16
II	Azithromycin[b]	0.015–64	≤ 2	4	≥ 8
	Clindamycin[b]	0.03–16	≤ 2	4	≥ 8
	Erythromycin	0.03–64	≤ 8	16	≥ 32
	Gentamicin[b]	0.12–32	≤ 2	4	≥ 8
	Nalidixic acid[b]	4–64	≤ 16	32	≥ 64
III	Florfenicol[b,c]	0.03–64	≤ 4	N/A	N/A
	Tetracycline	0.06–64	≤ 4	8	≥ 16
IV					

Roman numerals I to IV indicate the ranking of antimicrobials based on importance in human medicine as outlined by the Veterinary Drugs Directorate.

S = susceptible. I = intermediate susceptibility. R = resistant. N/A = not applicable.

[a] CLSI M45-A2.

[b] No Clinical and Laboratory Standards Institute interpretive criteria for *Campylobacter* were available for this antimicrobial. Breakpoints were based on the distribution of minimal inhibitory concentrations and were harmonized with those of the National Antimicrobial Resistance Monitoring System.

[c] For florfenicol, only a susceptible breakpoint has been established. In this report, we therefore only report the proportion of isolates non-susceptible.

Data analysis

Human and agri-food surveillance

Data management

Laboratory data from human and agri-food surveillance components originated in 2 computer programs (NML@Winnipeg Labware and NML@Guelph and NML@Saint-Hyacinthe Labware) and were subsequently transferred to a central data repository using intermediary computer software[151]. Data were then transferred to a SAS®-based harmonized database[152] called the Data Extraction and Analysis (DEXA) application. Additional antimicrobial resistance variables used for analysis were derived within the DEXA application; this application was also used as a central data access point.

Recovery rate

For Retail Meat Surveillance, Abattoir Surveillance, and the Farm Surveillance components, recovery rate was defined as the number of positive bacterial culture results divided by the total number of samples submitted for culture.

Resistant isolates

The percentage of isolates with resistance to one or more antimicrobials was defined as the number of isolates resistant to at least one antimicrobial divided by the total number of isolates tested for each antimicrobial, multiplied by 100.

The breakpoints used for interpretation of antimicrobial susceptibility results are listed in Table 5. 7 and Table 5. 8 (see the previous section). Intermediate Minimum Inhibitory Concentration (MIC) values were categorized as susceptible for all analyses. A new ceftriaxone breakpoint was officially adopted by the CLSI in January 2010 and was applied to all CIPARS data, including historical data. A new Enterobacteriaceae plate, CMV4AGNF, was utilized beginning in January 2016. Notable changes to the new plate included:

- The removal of ceftiofur (Category I)
- The addition of meropenem (Category I)
- The adjustment of the azithromycin MIC susceptibility testing range (0.25 to 32 µg/mL)
- The changing of the streptomycin breakpoint to greater than or equal to 32 µg/mL.

Resistance patterns

The total number of antimicrobials in each resistance pattern was calculated by summing the number of antimicrobials to which each isolate was resistant. The most common resistance pattern may include patterns with only 1 antimicrobial. In this case, like for the most common patterns including 2 or more antimicrobials, the number of isolates reported includes only those resistant to this specific pattern (i.e., without any additional resistance to other antimicrobials).

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[151] Oracle®, Oracle Corp., Redwood Shores, CA, USA.

[152] SAS® 9.3, SAS Institute Inc., Cary, NC, USA.

Statistical analysis

Data were analyzed with various statistical software[153], and outputs were exported into a spreadsheet application[154]. All tables and figures were generated with the spreadsheet application.

For Farm Surveillance, statistical analyses were performed to account for clustering of antimicrobial resistance within feedlot beef herds, swine herds, chicken flocks or turkey flocks through generalized estimating equations (GEE)[155]. All statistical models included a binary outcome, logit-link function, and exchangeable correlation structure. Null binomial response models were used to estimate the prevalence of resistance to each antimicrobial. From each null model, the intercept (β_0) and 95% confidence intervals were used to calculate population-averaged prevalence estimates with the formula $[1 + \exp(-\beta_0)]^{-1}$. When the prevalence was 0%, a model was run with a single positive isolate to determine the upper confidence interval only.

Temporal analysis

Temporal analyses were performed for selected antimicrobials. Only 1 antimicrobial per antimicrobial class was selected among those antimicrobials commonly used in the agri-food and/or human sectors. Some antimicrobials were excluded from the temporal analyses for the following reasons:

- Resistance to the antimicrobial was absent or at a very low prevalence, or the breakpoint was debatable and other antimicrobials could be used to provide a surrogate measure of resistance or intermediate susceptibility (e.g., nalidixic acid for ciprofloxacin).
- The isolate was cross-resistant to another selected antimicrobial (e.g., amoxicillin-clavulanic acid and ceftiofur).
- The antimicrobial has been banned for use in the agri-food sector, and resistance to this drug is maintained because of the use of another/other antimicrobial(s) (e.g., chloramphenicol).

Logistic regression models (asymptotic or exact depending on prevalence of the outcome variable) were developed with year as an independent categorical variable. Data were analyzed with commercial software[156]. Farm Surveillance data were adjusted for clustering at the herd level for grower-finisher pigs and flock level for broiler chickens. Components with regional or provincial temporal analysis had the current proportion of isolates resistant to a specific antimicrobial compared to those proportions observed in the previous surveillance year and 5 years previously. For broiler chickens, the 2016 data was compared to 2015 and 2013 data. For components with national temporal analysis, the current proportion of isolates resistant to a specific antimicrobial were compared to those proportions observed in the previous surveillance year, 5 years previously (for comparison between components), and 10 years previously (or the first year of surveillance). In a few specific instances, the first comparison year may vary to reflect the implementation of new CIPARS components (e.g., 2006 for the Farm Surveillance component in grower-finisher pigs and addition of the broiler

[153] SAS® 9.3; and Stata® 13 SE, Stata Corp., College Station, TX, USA.

[154] Microsoft® Excel 2010, Microsoft Corp.

[155] PROC GENMOD, SAS® 9.3.

[156] Stata ®13 SE.

chicken Farm Surveillance component in 2013). For ampicillin and ceftriaxone (previously ceftiofur), special temporal analyses have been conducted for *E. coli* and *Salmonella* isolated from retail chicken or abattoir chickens to compare the current year's data with that of 2004 and 2006. This was due to a change in ceftiofur use practices by Québec chicken hatcheries in early 2005 and in 2007 (start and end of the voluntary period of withdrawal respectively). These special analyses were also conducted for human *Salmonella* Heidelberg isolates because this human serovar was suspected to originate from chicken. A *P*-value less than or equal to 0.05 was considered significant for all temporal analyses.

Antimicrobial classification

Categorization of antimicrobials based on importance in human importance

Categories of antimicrobials used in this report were taken from the document Categorization of Antimicrobial Drugs Based on Importance in Human Medicine[157] by Health Canada's Veterinary Drugs Directorate (Table 5. 9). Antimicrobials are considered to be of Very High Importance in Human Medicine (Category I) when they are essential for the treatment of serious bacterial infections and there is no or limited availability of alternative antimicrobials for effective treatment. These antimicrobials include amoxicillin-clavulanic acid, ceftiofur[158], ceftriaxone, ciprofloxacin, and telithromycin. Antimicrobials of High Importance in Human Medicine (Category II) consist of those that can be used to treat a variety of infections, including serious infections, and for which alternatives are generally available. Bacteria resistant to antimicrobials of this category are generally susceptible to Category I antimicrobials, which could be used as alternatives. Antimicrobials of Medium Importance in Human Medicine (Category III) are used in the treatment of bacterial infections for which alternatives are generally available. Infections caused by bacteria resistant to these antimicrobials can, in general, be treated with Category II or I antimicrobials. Antimicrobials of Low Importance in Human Medicine (Category IV) are currently not used in human medicine.

[157] Health Canada. 2009. Categorization of Antimicrobial Drugs Based on Importance in Human Medicine. Version April, 2009. Available at: https://www.canada.ca/en/health-canada/services/drugs-health-products/veterinary-drugs/antimicrobial-resistance/categorization-antimicrobial-drugs-based-importance-human-medicine.html. Accessed July 2017.

[158] Ceftiofur is licensed for use in animals only. Resistance to ceftiofur is generally detected in combination with resistance to amoxicillin-clavulanic acid, cefoxitin, ampicillin and ceftriaxone (A2C-AMP-CRO resistance pattern).

Table 5. 9 Categorization of antimicrobial drugs based on importance in human medicine class, 2016

Category of importance in human medicine		Antimicrobial class
I	Very high importance	Carbapenems Cephalosporins – the third and fourth-generations Fluoroquinolones Glycopeptides Glycylcyclines Ketolides Lipopeptides Monobactams Nitroimidazoles (metronidazole) Oxazolidinones Penicillin-β-lactamase inhibitor combinations Polymyxins (colistin) Therapeutic agents for tuberculosis (e.g. ethambutol, isoniazid, pyrazinamide, and rifampin)
II	High importance	Aminoglycosides (except topical agents) Cephalosporins – the first and second-generations (including cephamycins) Fusidic acid Lincosamides Macrolides Penicillins Quinolones (except fluoroquinolones) Streptogramins Trimethoprim-sulfamethoxazole
III	Medium importance	Aminocyclitols Aminoglycosides (topical agents) Bacitracins Fosfomycin Nitrofurans Phenicols Sulfonamides Tetracyclines Trimethoprim
IV	Low importance	Flavophospholipols Ionophores

Roman numerals I to IV indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

List of antimicrobials from the farm broiler chicken and turkey questionnaire

Table 5. 10 List of antimicrobials from the broiler chicken and turkey questionnaire database for each ATCvet class, 2016

	ATCvet class	Antimicrobial
Antimicrobials administered via feed		
II	Aminoglycosides, other (QJ01GB)	Neomycin (QJ01GB05)
		Apramycin (QJ01GB90)
	Lincosamides (QJ01FF)	Lincomycin (AJ01FF02)
	Lincosamides-aminocyclitol combinations (QJ01RA94)	Lincomycin-spectinomycin
	Macrolides (QJ01FA)	Erythromycin (QJ01FA01)
		Tylosin (QJ01FA90)
	Penicillins (QJ01RA)	Penicillin (QJ01RA01)
		Procaine benzylpenicillin (QJ01CE09)
	Streptogramins (QJ01FG)	Virginiamycin (QJ01FG90)
III	Bacitracins (QA07AA)	Bacitracin (QA07AA93)
	Sulfonamides, plain and in combination, intestinal (QP51AG)	Sulfamethazine (No ATCvet code)
		Trimethoprim-sulfadiazine (No ATCvet code)
	Tetracyclines (QJ01AA)	Chlortetracycline (QJ01AA03)
		Oxytetracycline (QJ01AA06)
		Tetracycline (QJ01AA07)
IV	Flavophospholipids	Bambermycin (No ATCvet code)
	Ionophores, agents against protozoal diseases (QP51A)	Lasalocid (QP51AH02)
		Maduramicin (QP51AX10)
		Monensin (QP51AH03)
		Narasin (QP51AH04)
		Narasin-nicarbazin combination (QP51AH54)
		Salinomycin (QP51AH01)
N/A	Arsenicals, agents against protozoal diseases (QP51AD)	4-Nitrophenylarsonic acid (No ATCvet code)
	Chemical coccidiostats, other protozoal (QP51AX)	Amprolium (QP51AX09)
		Clopidol (No ATCvet code)
		Decoquinate (QP51AX14)
		Diclazuril (QP51AJ03)
		Nicarbazin (QP51AE03)
		Robenidine (QP51AX13)
		Zoalene/dinitolmide (QP51AX12)
	Orthosomycin	Avilamycine (No ATCvet code)

ATC = Anatomical Therapeutic Chemical.

Roman numerals I to IV indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

N/A = not applicable (no classification available at the time of writing of this report).

The ATCvet system for classification of veterinary medicines is based on the same overall principles as the ATC system for substances used in human medicine. This system is a tool for exchanging and comparing data on drug use in veterinary medicine at international, national or local levels[159].

[159] World Health Organization Collaborating Center for Drug Statistics Methodology. ATCvet. Available at: www.whocc.no/atcddd. Accessed May 2017.

Table 5. 10 List of antimicrobials from the broiler chicken and turkey questionnaire database for each ATCvet class, 2016 (continued)

ATCvet class		Antimicrobial
Antimicrobials administered via drinking water		
I	Fluoroquinolones	Enrofloxacin (QJ01MA90)
II	Aminoglycosides, other (QJ01GB)	Neomycin (QJ01GB05)
		Apramycin (QJ01GB90)
	Lincosamides, combination with other antimicrobials	Lincomycin-spectinomycin (QJ01RA94)
	Macrolides (QJ01FA)	Erythromycin (QJ01FA01)
		Tylosin (QJ01FA90)
	Penicillins, with extended spectrum (QJ01CA)	Amoxicillin (QJ01CA04)
	Penicillins (QJ01RA)	Penicillin (QJ01RA90)
	Penicillins, combination with other antibacterials (QJ01RA)	Penicillin-streptomycin (QJ01RA01)
III	Amphenicols (QJ01BA)	Florfenicol (QJ01BA90)
	Sulfonamides, plain and in combination, intestinal (QP51AG)	Sulfamethazine (No ATCvet code)
		Sulfaquinoxaline (QP51AG03)
		Sulfaquinoxaline-pyrimethamine (No ATCvet code)
	Tetracyclines (QJ01AA)	Chlortetracycline (QJ01AA03)
		Oxytetracycline (QJ01AA06)
		Tetracycline (QJ01AA07)
	Tetracyclines and combinations (QJ01RA90)	Oxytetracycline-neomycin (No ATCvet code)
		Tetracycline-neomycin (No ATCvet code)
Antimicrobials administered via subcutaneous or *in ovo* injections		
I	Third-generation cephalosporins (QJ01DD)	Ceftiofur (QJ01DD90)
II	Aminoglycosides, other (QJ01GB)	Gentamicin (QJ01GB03)
	Lincosamides-aminocyclitol combinations (QJ01RA94)	Lincomycin-spectinomycin (No ATCvet code)

ATC = Anatomical Therapeutic Chemical.

N/A = not applicable (no classification available at the time of writing of this report).

Roman numerals I to IV indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

The ATCvet system for classification of veterinary medicines is based on the same overall principles as the ATC system for substances used in human medicine. This system is a tool for exchanging and comparing data on drug use in veterinary medicine at international, national or local levels[160].

[160] World Health Organization Collaborating Center for Drug Statistics Methodology. ATCvet. Available at: www.whocc.no/atcddd. Accessed May 2017.

List of antimicrobials from the farm swine questionnaire

Table 5. 11 List of antimicrobials from the farm swine questionnaire database for each ATCvet class, 2016

	ATCvet class	Antimicrobial
I	Third-generation cephalosporins (QJ01DD)	Ceftiofur (QJ01DD90)
	Fluoroquinolones	Enrofloxacin (QJ01MA90)
II	Amphenicols (QJ01BA)	Florfenicol (QJ01BA90)
	Penicillins with extended spectrum (QJ01CA)	Ampicillin (QJ01CA01)
		Amoxicillin (QJ01CA04)
	β-Lactamase sensitive penicillins (QJ01CE)	Penicillin (QJ01CE01)
	Combination of sulfadoxine and trimethoprim (QJ01EW)	Trimethoprim-sulfadoxine (QJ01EW13)
	Macrolides (QJ01FA)	Erythromycin (QJ01FA01)
		Tylosin (QJ01FA90)
		Tilmicosin (QJ01FA91)
		Tulathromycin (QJ01FA94)
	Lincosamides (QJ01FF)	Lincomycin (QJ01FF02)
	Streptogramins (QJ01FG)	Virginiamycin (QJ01FG90)
	Other aminoglycosides (QJ01GB)	Neomycin (QJ01GB05)
	Combinations of antibacterials (QJ01RA)	Penicillin-streptomycin (QJ01RA01)
		Chlortetracycline-sulfamethazine-penicillin (QJ01RA90)
		Oxytetracycline-neomycin (QJ01RA90)
		Tetracycline-neomycin (QJ01RA90)
		Lincomycin-spectinomycin (QJ01RA94)
	Other antibacterials (QJ01XX)	Spectinomycin (QJ01XX04)
III	Tetracyclines (QJ01AA)	Chlortetracycline (QJ01AA03)
		Oxytetracycline (QJ01AA06)
		Tetracycline (QJ01AA07)
		Chlortetracycline, combinations (QJ01AA53)
	Sulfonamides (QJ01EQ)	Combinations of sulfonamides (QJ01EQ30)
	Pleuromutilins (QJ01XQ)	Tiamulin (QJ01XQ01)
	Other antibacterials (QJ01XX)	Bacitracin (QJO1XX10)
IV	No ATCvet code	Bambermycin (No ATCvet code)
	Pyranes and hydropyranes (QP51AH)	Salinomycin (QP51AH01)

ATC = Anatomical Therapeutic Chemical.

Roman numerals I to IV indicate categories of importance to human medicine as outlined by the Veterinary Drugs Directorate.

The ATCvet system for classification of veterinary medicines is based on the same overall principles as the ATC system for substances used in human medicine. This system is a tool for exchanging and comparing data on drug use in veterinary medicine at international, national or local levels[161].

[161] World Health Organization Collaborating Center for Drug Statistics Methodology. ATCvet. Available at: www.whocc.no/atcddd. Accessed May 2017.

Appendix

Abbreviations

Canadian provinces, territories, and regions

Provinces

BC British Columbia
AB Alberta
SK Saskatchewan
MB Manitoba
ON Ontario
QC Québec
NB New Brunswick
NS Nova Scotia
PE Prince Edward Island
NL Newfoundland and Labrador

Territories

YT Yukon
NT Northwest Territories
NU Nunavut

Regions[162]

Prairies: AB, SK, MB
Maritimes: NB, NS, PE
Atlantic: NB, NS, PE, NL

Antimicrobials

AMC Amoxicillin-clavulanic acid
AMP Ampicillin
AZM Azithromycin
CHL Chloramphenicol
CIP Ciprofloxacin
CLI Clindamycin
CRO Ceftriaxone
ERY Erythromycin
FLR Florfenicol
FOX Cefoxitin
GEN Gentamicin
MEM Meropenem
NAL Nalidixic acid
SSS Sulfisoxazole
STR Streptomycin
SXT Trimethoprim-sulfamethoxazole
TEL Telithromycin
TET Tetracycline
TIO Ceftiofur

[162] In 2016, not all provinces are represented in each surveillance component for the Prairies and the Atlantic region.

Important resistance patterns

A2C-AMP Amoxicillin-clavulanic acid, cefoxitin, ceftiofur, and ampicillin

ACSSuT Ampicillin, chloramphenicol, streptomycin, sulfisoxazole, and tetracycline

Other abbreviations

ABF antibiotic-free program

APP *Actinobacillus pleuropneumoniae*

APEC Avian pathogenic *Escherichia coli*

IBV Infectious Bronchitis Virus

PCVAD Porcine Circovirus Associated Disease

PDAR Pig-days at risk

PED Porcine Epidemic Diarrhea

PRRS Porcine Reproductive and Respiratory Syndrome

RWA Raised without antibiotics

TGE Transmissible gastroenteritis

VDD Veterinary Drugs Directorate, Health Canada

Supplemental data

Table A. 1 Canadian Defined Daily Doses for animals (DDDvetCA) standard values for broiler chickens and turkeys

Route of administration	European route of administration	Antimicrobial	Average dose basis	Average dose	DDDvetCA ($mg_{drug}/kg_{animal}/day$)
Feed	Oral	Avilamycin	TP	22.5	2.9
		Bacitracin	TP	77.9	10.1
		Chlortetracycline	TP	128.3	16.7
		Erythromycin	TP	220.0	28.6
		Oxytetracycline	TP	128.3	16.7
		Procaine penicillin G	TP	41.3	5.4
		Sulfadiazine-trimethoprim[a] (ELDU)	TP	83.3	10.8
		Trimethoprim-sulfadiazine[a] (ELDU)	TP	16.8	2.2
		Tylosin	TP	200.0	26.0
		Virginiamycin	TP	22.0	2.9
Injectable	Parenteral	Ceftiofur (ELDU)	TP	2.6	2.6
		Gentamicin	TP	10.8	10.8
		Lincomycin-spectinomycin[a] (ELDU)	TP	6.0	6.0
		Spectinomycin-lincomycin[a] (ELDU)	TP	12.0	12.0
Water	Oral	Amoxicillin	TP	52.0	12.0
		Apramycin (ELDU)	TP	100.0	23.0
		Enrofloxacin (ELDU)	TP	25.0	5.8
		Erythromycin	TP	86.7	19.9
		Lincomycin	TP	16.0	3.7
		Lincomycin-spectinomycin[a]	TP	277.5	63.8
		Neomycin	TP	94.8	21.8
		Oxytetracycline	TP	81.9	18.8
		Penicillin G	TP	178.3	41.0
		Penicillin G (supp)	TP	16.5	3.8
		Spectinomycin-lincomycin[a]	TP	555.0	127.7
		Streptomycin (supp)	TP	85.2	19.6
		Sulfamethazine	TP	1027.8	236.4
		Sulfaquinoxaline	TP	317.2	72.9
		Tetracycline	TP	93.1	21.4
		Tylosin	TP	312.5	71.9
		Sulfaquinoxaline-pyrimethamine[a]	TP	48.8	11.2

See corresponding footnotes on next page.

Table A. 1 Canadian Defined Daily Doses for animals (DDDvetCA) standard values for broiler chickens and turkeys (continued)

Extra-label drug use (ELDU) poultry, dose, or doses were derived from expert opinion or veterinary consultations[163].

TP = treatment and prevention. GP = growth promotion. Supp = supplement or product has lower level of drug.

Average dose = average of all doses indicated in available products listed in the Compendium of Medicating Ingredients Brochure[164] and Compendium of Veterinary Products[165]; values were multiplied to the standard values for either feed or water intake (see Table A.3) to obtain the DDDvetCA standard for poultry.

DDDvetCA = Canadian Defined Daily Doses for animals (average labelled dose) in milligrams per kilogram broiler chicken or turkey per day (mg_{drug}/kg_{animal}/day).

DDDvetCA standards for products with much lower dosing than preventive and treatment uses such as ionophores, chemical coccidiostats and products intended mainly for growth promotion (flavophospolipids and penicillin G via feed) were developed and are available in the previous year's report or can be obtained upon request. The total number of DDDvetCA for these products are not included in this report.

[a] Antimicrobials with hyphen is a combination drug; the values for this row pertain to the first drug in the sequence.

[163]Canadian Association of Poultry Veterinarians. Available at: http://www.capv-acva.ca/BroilerChicken.htm. Accessed January 2017.

[164]CFIA, 2016b: Compendium of Medicating Ingredient Brochure. Available at: http://www.inspection.gc.ca/animals/feeds/medicating-ingredients/eng/1300212600464/1320602461227. Accessed on January 2017.

[165] Canadian Animal Health Institute, 2016: Compendium of Veterinary Products. Available at: https://bam.naccvp.com/?u=country&p=msds. Accessed on January 2017.

Table A. 2 Canadian Defined Daily Doses for animals (DDDvetCA) standard values for grower-finisher pigs

Route of administration	Antimicrobial	Average dose basis	Average dose	DDDvetCA (mg_{drug}/kg_{animal}/day)
Feed	Avilamycin	TP	80.0	3.2
	Bacitracin	TP	113.4	4.5
	Bambermycin	GP	3.0	0.1
	Chlortetracycline	TP	260.3	10.4
	Lincomycin	TP	124.7	5.0
	Lincomycin-spectinomycin[a]	TP	22.0	0.9
	Narasin	GP	15.0	0.6
	Oxytetracycline	TP	189.4	7.6
	Penicillin G	TP	32.1	1.3
	Salinomycin	GP	25.0	1.0
	Spectinomycin-lincomycin[a]	TP	22.0	0.9
	Sulfamethazine	TP	110.0	4.4
	Tiamulin	TP	116.0	4.6
	Tilmicosin	TP	300.0	12.0
	Tylosin	TP	77.0	3.1
	Tylvalosin	TP	42.5	1.7
	Virginiamycin	TP	82.5	3.3
Injectable	Ampicillin	TP	6.0	6.0
	Benzathine Penicillin G-combination[a]	TP	1.2	1.2
	Ceftiofur	TP	3.0	3.0
	Ceftiofur-long acting	TP	1.0	1.0
	Enrofloxacin	TP	7.5	7.5
	Florfenicol	TP	7.5	7.5
	Gentamicin	TP	1.3	1.3
	Lincomycin	TP	10.0	10.0
	Oxytetracycline	TP	5.9	5.9
	Procaine penicillin G	TP	13.5	13.5
	Procaine penicillin G-long acting	TP	6.7	6.7
	Procaine penicillin G-combination[a]	TP	1.5	1.5
	Sulfadoxine-trimethoprim[a]	TP	13.3	13.3
	Tiamulin	TP	11.0	11.0
	Trimethoprim-sulfadoxine[a]	TP	2.4	2.4
	Tulathromycin	TP	0.3	0.3
	Tylosin	TP	5.5	5.5

See corresponding footnotes on the next page.

Table A. 2 Canadian Defined Daily Doses for animals (DDDvetCA) standard values for grower-finisher pigs (continued)

Route of administration	Antimicrobial	Average dose basis	Average dose	DDDvetCA (mg_{drug}/kg_{animal}/day)
Water	Amoxicillin	TP	200.0	20.0
	Apramycin	TP	100.0	10.0
	Lincomycin	TP	33.3	3.3
	Lincomycin-spectinomycin[a]	TP	22.2	2.2
	Neomycin	TP	115.9	11.6
	Oxytetracycline	TP	146.4	14.6
	Penicillin G	TP	178.0	17.8
	Spectinomycin-lincomycin[a]	TP	44.4	4.4
	Sulfamerazine (supp)	TP	32.9	3.3
	Sulfamethazine	TP	789.7	79.0
	Sulfamethazine (supp)	TP	62.8	6.3
	Sulfapyridine	TP	333.3	33.3
	Sulfathiazole	TP	462.1	46.2
	Sulfathiazole (supp)	TP	103.0	10.3
	Tetracycline	TP	85.9	8.6
	Tiamulin	TP	49.0	4.9
	Tylosin	TP	166.5	16.7
	Tylvalosin	TP	50.0	5.0
Bolus	Neomycin (supp)	TP	7.5	7.5
	Neomycin	TP	19.7	19.7
	Oxytetracycline	TP	29.3	29.3
	Spectinomycin	TP	18.8	18.8
	Succinylsulfathiazole (supp)	TP	36.0	36.0
	Sulfaguanidine	TP	83.8	83.8
	Sulfamethazine	TP	118.1	118.1
	Sulfanilamide	TP	73.1	73.1
	Sulfathiazole	TP	57.4	57.4
	Tetracycline	TP	15.3	15.3
	Toltrazuril	TP	20.0	20.0

TP = treatment and prevention. GP = growth promotion. Supp = supplement or product has lower level of drug.

Average dose = average of all doses indicated in available products listed in the Compendium of Medicating Ingredients Brochure[166] and Compendium of Veterinary Products[167]; values were multiplied to the standard values for either feed or water intake (in Table A.4) to obtain the Canadian DDDvetCA standard values for pigs.

DDDvetCA = Canadian Defined Daily Doses for animals (average labelled dose) in milligrams per kilogram pig per day (mg_{drug}/kg_{animal}/day).

[a] Antimicrobials with hyphen is a combination drug; the values for this row pertain to the first drug in the sequence.

[166] CFIA, 2016b: Compendium of Medicating Ingredient Brochure. Available at: http://www.inspection.gc.ca/animals/feeds/medicating-ingredients/eng/1300212600464/1320602461227. Accessed on January 2017.

[167] Canadian Animal Health Institute, 2016: Compendium of Veterinary Products. Available at: https://bam.naccvp.com/?u=country&p=msds. Accessed on January 2017.

Table A. 3 Conversion factors for broiler chickens and other poultry

Standard values feed and water intake	Poultry
Canadian standard turkey poult weight (kg at hatch)[a]	0.06
Canadian standard chick weight (kg at hatch)[a]	0.042
Canadian standard broiler weight (kg)[a]	1.0
Canadian standard feed to weight ratio	0.13
Canadian standard water to weight ratio	0.23
ESVAC feed to weight ratio (kg feed/kg animal)[b]	0.13
ESVAC water to weight ratio (L water/kg animal)[b]	0.23

ESVAC = European Surveillance of Veterinary Antimicrobial Consumption.

DDDA = Defined daily dose for animals.

[a] As per expert opinion.

[b] ESVAC Principles of DDDA Assignment[168].

Table A. 4 Conversion factors for swine

Standard values feed and water intake	Swine
Canadian standard piglet weight (kg)	4.00
Canadian standard grower-finisher pig weight (kg)	65.00
Canadian standard water intake (for a 65 kg pig) (L)[a]	6.50
Canadian standard feed intake (for a 65 kg pig) (kg)	2.18
Canadian standard feed to weight ratio	0.04
Canadian standard water to weight ratio	0.10
ESVAC Feed to weight ratio (kg feed/kg animal)	0.04
ESVAC Water to weight ratio (L water/kg animal)	0.10

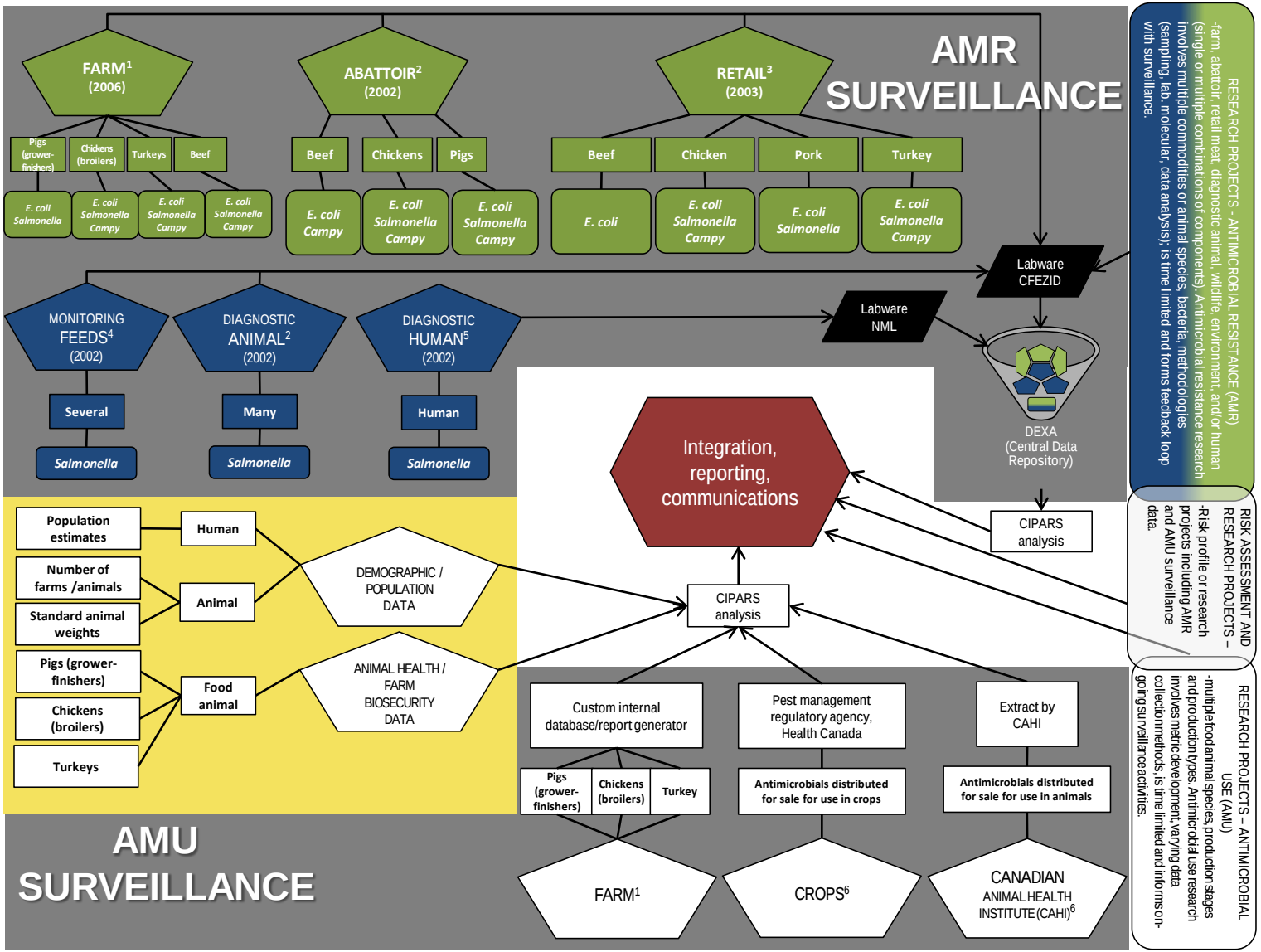
ESVAC = European Surveillance of Veterinary Antimicrobial Consumption.

[a] Water consumption estimation: Used 10% body weight to estimate. Alternatively could use formula: 0.788 + (2.23 x kg of daily feed intake) + [0.367 x kg pig body weight (0.06)][169].

[168] Available at: http://www.ema.europa.eu/ema/index.jsp?curl=pages/includes/document/document_detail.jsp?webContentId=WC500184369&mid=WC0b01ac058009a3dc. Accessed January 2017.

[169] Available at: http://www.sites.ext.vt.edu/newsletter-archive/livestock/aps-06_07/aps-349.html. Accessed on January 2017. Available at: http://www.sites.ext.vt.edu/newsletter-archive/livestock/aps-06_07/aps-349.html. Accessed on January 2017.

Figure A. 1 Summary of the CIPARS samples and data flow, 2016



See corresponding footnotes on the next page.

Figure A. 1 Summary of the CIPARS samples and data flow, 2016 (continued)

= Active surveillance; primary data, primarily for prevalence estimation. = Passive surveillance; secondary data, primarily for AMR detection.
CFEZID = Centre for Food-borne, Environmental and Zoonotic Infectious Diseases. **NML** = National Microbiology Laboratory.

[1–7] **CIPARS project leads:** 1– (grower-finisher pigs)–David Léger (david.leger@canada.ca) and Sheryl Gow (sheryl.gow@canada.ca); 1– (broiler chickens and turkeys)–Agnes Agunos (agnes.agunos@canada.ca); 2–Anne Deckert (anne.deckert@canada.ca); 3–Brent Avery (brent.avery@canada.ca); 4–Jane Parmley (jane.parmley@canada.ca); 5–Michael Mulvey (michael.mulvey@canada.ca); 6–Carolee Carson (carolee.carson@canada.ca).
CIPARS Program Coordinators: Rebecca Irwin (rebecca.irwin@canada.ca); Richard Reid-Smith (richard.reid-smith@canada.ca); Michael Mulvey (michael.mulvey@canada.ca).