CDFA AUS Multi-Year Report on the California-Specific NARMS Data—2014-2023
Salmonella

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Scope of Report and California Significance: A core mission of the California Department of Food and Agriculture (CDFA) Antimicrobial Use and Stewardship (AUS) program is to inform efforts to mitigate antibiotic resistance and identify emerging areas of concern and potential public health threats. To support this mission, and as data is available, AUS will generate regular reports to monitor antibiotic resistance and susceptibility trends of four common bacteria, some of which cause foodborne illnesses in humans, and others that are monitored as indicators through the National Antimicrobial Resistance Monitoring System (NARMS). The NARMS data for these reports will be sourced from samples collected from food-producing animals at the time of slaughter in California.

Disclaimer: Antibiotic resistance, which includes measures of reduced susceptibility, is a highly complex problem influenced by many factors. The data CDFA AUS have presented here can be used to monitor several years of bacterial resistance and susceptibility to drugs important in human medicine. These bacteria can be common causes of foodborne illness or may be monitored as indicator bacteria; both are found in samples from livestock slaughtered in California. These data are best used to monitor trends over multiple years; yet, drawing conclusions to prompt specific interventions should be avoided. Additionally, caution should be applied when making broad generalizations or host species comparisons, understanding these data's limitations in reflecting differences in production practices for these animal species. Finally, caution must be applied when interpreting these data, as they are not representative of on-farm resistance profiles due to cross-contamination during transport, animal holding, and processing.[1-3] They, therefore, should **not** be used as a surrogate to reflect the impact of on-farm antibiotic use on public health.

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Introduction

Antibiotics are life-saving drugs vital to protect people and animals from bacterial infections. Antibiotic resistance occurs when bacteria evolve in a way that renders antibiotics ineffective. Resistance can be intrinsic due to specific structural or functional properties of the bacteria, but it can also occur naturally secondary to environmental pressures and can be acquired from other bacteria. Resistance to antibiotics makes common infections in people and animals a challenge, or even impossible, to treat. While the number of human deaths in the US from antibiotic resistance has decreased since 2013, there remain approximately 2.8 million antibiotic-resistant infections diagnosed per year, causing 35,000 fatalities.[4] The impact of antibiotic resistance is observed in a high percentage of human foodborne illnesses associated with antibiotic-resistant bacteria, resulting in increased morbidity and mortality.[5] In California, the most recent CDC data, from 2017, reported 107 foodborne illness outbreaks, a 9% increase from 2016, highlighting the ongoing need to monitor foodborne illness and resistance trends.[6,7]

Antibiotic resistance in foodborne bacteria is a significant public health threat. In response to this global concern, the National Antimicrobial Resistance and Monitoring System (NARMS) program was developed in the United States. NARMS is a collaboration between the Centers for Disease Control and Prevention (CDC), the Food and Drug Administration (FDA), and the US Department of Agriculture (USDA) Food Safety and Inspection Services (FSIS). The purpose of NARMS is to provide national surveillance in the US of drug-resistant bacteria that cause foodborne illness by collecting samples from clinically ill humans (CDC), retail meats (FDA), and food animals at the time of slaughter (USDA FSIS). NARMS' data are regularly published on their online dashboard.[8]

In a concurrent effort to monitor antibiotic resistance trends, the California Department of Food and Agriculture (CDFA) established the Antimicrobial Use and Stewardship (AUS) program. This first-in-the-nation program implements the directives of Food and Agricultural Code (FAC) 14400-14408 to provide educational tools for veterinarians and producers on disease prevention and optimal antibiotic use in food animals and to conduct and disseminate evidence-based research on antibiotic resistance trends.

CDFA AUS generates California-specific reports summarizing NARMS information from USDA FSIS sampling, as provided to CDFA AUS via Freedom of Information Act (FOIA) requests. These reports aim to evaluate antibiotic susceptibility trends in the most-reported bacterial causes of foodborne illness, as well as key indicator bacteria, in samples collected from food animals slaughtered in California and in fulfillment of the mandates of FAC 14405 (a) and (b). This CDFA AUS Multi-Year *Salmonella* Report provides summary data for USDA FSIS NARMS *Salmonella* isolates collected from 2014 through 2023 from animals slaughtered in California.

NARMS Methodology

The complete sampling and laboratory methodologies used by FSIS processing facilities for sample collection and processing can be found online or by contacting USDA FSIS.[9,10]

Sample Collection

Samples are collected for the NARMS program at FSIS-regulated slaughter facilities across the United States. Only data from FSIS-regulated slaughter facilities in California are included in the California-specific results presented in this report. Notably, these data represent cattle, poultry, and swine that are both raised and slaughtered in California, as well as animals raised in other states but slaughtered in California.

Bacteria identified from testing conducted on NARMS samples by the USDA's Agricultural Research Service are *Salmonella*, *Escherichia coli* (*E. coli*), *Enterococcus*, and *Campylobacter*. *Salmonella* and *Campylobacter* are important causes of foodborne illness in people, whereas *Enterococcus* and *E. coli* are used as indicator bacteria to monitor resistance patterns to antibiotics utilized in the treatment of gram-positive and gram-negative bacterial infections, respectively, within the food supply. USDA FSIS collects samples at slaughter for the NARMS Cecal Sample Program, which are taken from the intestinal contents of cattle (including dairy and beef cows, steers, heifers, and veal), swine (market swine and sows), chickens, and turkeys. These samples, collected early in the slaughter process, are referred to as "cecal samples" throughout the report. The approach used by NARMS for sample collection, along with their data reporting methods and differing management, husbandry, and antibiotic use practices for various food animal species, complicates both the separation of NARMS data by commodity type for some species (e.g., beef vs. dairy cattle) and the grouping of other species, such as chickens and turkeys, into a single poultry category. Therefore, in this report, AUS presents the NARMS data categorized solely by animal species: cattle, chicken, turkey, and swine. This categorization aims to reduce inaccuracies in data reporting.

FSIS also collects samples as part of its routine verification testing program for Pathogen Reduction/Hazard Analysis Critical Control Point (PR/HACCP). These HACCP samples are taken after the point in the slaughter process where specific practices designed to prevent or eliminate contamination from disease-causing bacteria have already been implemented. Please note that these data are not included in this report.

Antibiotic Susceptibility Testing

The cecal samples collected for NARMS are tested for four target bacteria: *Salmonella*, *Campylobacter*, generic *E. coli*, and *Enterococcus*. The purified bacteria isolated from these samples are referred to as bacterial isolates. These isolates undergo further testing, known as antibiotic susceptibility testing (AST). Details on the corresponding AST methodology for each antibiotic type used for *Salmonella* isolate testing are available in **Appendix A.** AST testing identifies whether the bacterial isolate is considered susceptible to a panel of antibiotics. This is accomplished by determining the tested concentration of an antibiotic that inhibits bacterial growth, known as the minimum inhibitory concentration (MIC). The MIC value can be used to categorize the bacteria based on their relation to established cutoff values. NARMS utilizes standardized cutoff values, called breakpoints, established by the Clinical and Laboratory Standards Institute (CLSI) for *Enterococcus, Salmonella,* and *E. coli* or, in the case of *Campylobacter,* epidemiological cut-off values (ECOFFs),[11] to interpret MIC values. CLSI breakpoints categorize bacterial isolates as susceptible, intermediate, or resistant to a tested antibiotic based on clinical, pharmacological, and microbiological data. In contrast, ECOFFs, which are also specific to the bacterial species-antibiotic combination, do not factor clinical parameters or host species into the interpretation of results and distinguish bacterial populations as wild-type and non-wild-type strains. NARMS classifies *Salmonella* isolates as either susceptible, intermediate, or resistant using the interpretive criteria as described in **Appendix B.** When tested using a standardized antibiotic dosage, susceptible means that the drug is likely to be therapeutically effective against the bacterial isolate when using the same drug dose and route of administration. In contrast, a resistant isolate indicates that the drug is unlikely to be effective at achievable concentrations, while intermediate implies possible antibiotic effectiveness under specific dosing or site-of-infection conditions, but with less certainty. To avoid ambiguity associated with the intermediate category, this report will focus on reporting the percent resistance data only. Additionally, while AST results provide information regarding the susceptibility of a bacterial isolate to an antibiotic, it is important to note that this is a laboratory-based test with limitations and does not account for other factors that may impact bacterial susceptibility or resistance to a drug in a clinical setting.

The specific NARMS antibiotic panel used for testing depends on the bacteria being analyzed. The NARMS antibiotic panel used to test *Salmonella* isolates can be found in **Appendix C** of this report. Although the NARMS antibiotic panel and interpretive criteria are specific to human medicine, some of the antibiotics included in this panel are used therapeutically in food animals, while others are not. For those antibiotics that are not used in food animals, alternative drug formulations within the same antibiotic class may still be approved for such use. Additional details regarding this information are provided in **Appendix C**.

Whole Genome Sequencing

Whole genome sequencing (WGS) is a methodology used to enhance antibiotic resistance surveillance by identifying known antibiotic resistance genes that bacteria may possess. While for some bacteria, WGS may correlate highly with the resistance observed in the environment, not all antibiotic resistance is caused by genetic alterations, and bacteria carrying resistance genes do not necessarily display resistance in laboratory testing or a clinical setting.

Salmonella

General Overview

As one of the four leading bacterial causes of foodborne illness, *Salmonella* is a significant public health concern.[12,13] Causing over 1 million human foodborne infections and 400 deaths reported annually in the US, *Salmonella* is the third most costly foodborne pathogen.[12,13] This bacterium is capable of colonizing a wide range of hosts, including humans, livestock, poultry, amphibians, reptiles, and domestic and wild animals, and can also persist in food animal slaughter and processing environments, making it a central focus of One Health-related food safety initiatives.

Infection caused by *Salmonella* is commonly referred to as salmonellosis. In 85% of human cases, salmonellosis occurs following the ingestion of contaminated food, with the remainder of cases associated with consuming contaminated water, contact with infected animals, or transmission from person to person.[13] Common food sources associated with human salmonellosis include meat and egg products, as well as fruits and vegetables. In livestock, some *Salmonella* are considered normal inhabitants of the gastrointestinal tract and gallbladder,[13] and contamination of meat products during animal slaughter is often caused by carcass mishandling during processing. Egg products can be contaminated both externally, through contact with infected fecal material on the shell, and internally during egg development. Outbreaks in people are also frequently attributed to contact with backyard poultry, as well as reptiles. Finally, domestic animals, including pet dogs and cats, are also a significant risk factor for environmental contamination and transmission to humans.[14]

While gastrointestinal symptoms, including vomiting and abdominal pain, characterize most salmonellosis infections in people, some serovars can cause more invasive extraintestinal infection and systemic disease. At-risk populations for severe disease include children under five years of age, the elderly, and individuals with a weakened immune system. Notably, the use of certain medications, such as antacids and certain antibiotics, can disrupt the normal intestinal flora, increasing an individual's risk of developing an infection.[13]

In some animal species, *Salmonella* results in subclinical disease, whereas in others, pronounced clinical illness is common.[14] Salmonellosis in both poultry and swine can result in diarrhea in young animals and bloodstream infection.[15] In poultry, some *Salmonella* serovars target the reproductive tract, resulting in transmission of the bacteria to the developing egg, which is a significant route of transmission to people. In cattle, calf diarrhea, bloodstream infection in both adult cattle and calves, respiratory disease, and abortions can occur following infection with the host-adapted cattle serovar, *S.* Dublin, which can also cause systemic disease in people.[14,16] Animals with subclinical or asymptomatic infection are referred to as carriers. Carrier animals can shed the bacterium in their feces intermittently, making them important reservoirs for environmental contamination, as well as a direct source of transmission to people, especially during slaughter.[14] Rodents, flies, and other insects primarily acquire the bacterium through contact with infected wildlife and subsequently serve as important sources of transmission in the farm setting, contaminating animal feed and water.[14,17]

Human salmonellosis is typically self-limiting.[13] In instances where antibiotics are warranted, treatment decisions should be guided by AST results, clinical presentation, and local patterns of antibiotic resistance. First-line therapy for treating infections in people includes ampicillin, chloramphenicol, and potentiated sulfonamides.[14] The emergence of antibiotic-resistant strains and associated treatment failures has resulted in increased duration of hospitalization and deaths secondary to resistant *Salmonella* infections. The increasing frequency of multidrug-resistant strains and emerging resistance to other clinically relevant antibiotics, such as fluoroquinolones and third-generation cephalosporins, is complicating the treatment of salmonellosis, resulting in macrolides, such as azithromycin, becoming the empirical choice for infections.[13,14]

Many of the antibiotics used to treat *Salmonella* infections in people, such as chloramphenicol and azithromycin, are not approved for use in food animals in the US. The drugs that are approved for use in food animals are generally administered to animals suffering from diseases that pose significant risks to their health and welfare if left untreated. For more detailed information on approved antimicrobials in food animals and their use, please refer to **Appendix C**.

Number of Samples Screened and Isolates That Underwent AST

The number of samples screened as part of the NARMS Cecal Sample Program is facility-dependent and based on the production volume and the target number of bacterial isolates needed for AST as determined by NARMS, while aiming to make the data representative of the industry.[10] Cecal samples are obtained from individual cattle and swine, but are combined from five birds for chicken and turkey sampling procedures.[10]

The number of samples screened and *Salmonella* isolates obtained for the NARMS Cecal Sample Program from food animals slaughtered in California are presented in **Table 1**. The number of bacterial isolates that underwent AST by animal species is shown in **Table 2**. Please note that differences in data mining methodologies, timing of data synchronization, and variations in source system updates may cause discrepancies in the complex datasets used in this report. This impacts the ability to directly compare the number of samples and the number of isolates presented in this report. A total of 750 *Salmonella* isolates were obtained, and underwent AST, from screened NARMS cecal samples of the following animal species slaughtered in California between 2014 and 2023: 373 from adult cattle, 74 from chickens, 23 from turkeys, and 280 from swine.

Table 1. Number of NARMS Cecal Samples from California-Slaughtered Food Animals Screened for Salmonella and Screening Results, 2014-2023, by Animal Species.

Year		Cattle*	Chickens	Turkeys	Swine
2014	Null	1	0	0	0
	Negative	242	13	13	18
	Positive	23	0	0	31
2015	Null	0	0	0	0
	Negative	195	16	13	16
	Positive	26	2	2	18
2016	Null	4	0	1	0
	Negative	227	13	10	22
	Positive	24	0	4	41
2017	Null	0	0	0	0
	Negative	271	9	11	16
	Positive	32	7	2	49
2018	Null	0	0	0	0
	Negative	314	16	15	11
	Positive	47	12	3	57
2019	Null	4	1	0	0
	Negative	300	10	12	11
	Positive	51	18	3	29
2020	Null	16	3	1	9
	Negative	191	4	2	7
	Positive	22	1	1	6
2021	Null	17	1	0	7
	Negative	227	6	3	0
	Positive	17	1	0	2
2022	Null	12	0	0	16
	Negative	253	10	9	6
	Positive	48	11	3	21
2023	Null	31	0	0	11
	Negative	217	4	9	4
	Positive	39	16	4	7
Total		2851	174	121	415

* The cattle category represents adult animals and does not include bob veal isolates.

Table 2. Number of NARMS Salmonella Isolates from California-Slaughtered Food Animals that Underwent AST, 2014-2023, by Animal Species.

Year	Cattle*	Chickens	Turkeys	Swine
2014	23	0	0	31
2015	26	2	2	18
2016	24	0	4	41
2017	32	7	2	49
2018	47	11	3	57
2019	51	18	3	31
2020	43	4	1	17
2021	40	5	1	8
2022	48	11	3	21
2023	39	16	4	7
Total	373	74	23	280

* The cattle category represents adult animals and does not include bob veal isolates.

Note: NARMS does not conduct AST on all positive samples. The complete sampling and laboratory methodologies used by USDA FSIS processing facilities for sample collection and processing can be found online or by contacting USDA FSIS.

The yearly number of *Salmonella* isolates from each animal species used for AST from California-slaughtered food animals, except cattle, is frequently below 30. Thirty is the threshold AUS uses for statistical validity and improved predictive value when evaluating cumulative susceptibility data, as recommended by the CLSI M39 guidelines.[18] This means that, due to low numbers, the *Salmonella* AST data for isolates from California-slaughtered food animals tested through NARMS each year may not be representative of the larger population of *Salmonella* in animals slaughtered in California. Indeed, variations in resistance rates may result from analyzing a limited number of isolates rather than reflecting true changes in susceptibility.[19] While the data showing the percentage of resistant isolates are presented for each animal species below, interpretations of population trends in *Salmonella* susceptibility for isolates obtained from chickens, turkeys, and, for some years, cattle and swine cannot be made due to the limited number of isolates tested for these host species.

Number of *Salmonella* Isolates by Serovar

Salmonella is categorized into two species: *S. enterica* and *S. bongori*. Among these, *S. enterica* is the more common cause of infections in humans and can be divided into six subspecies. The subspecies *S. enterica* subsp. *enterica* accounts for about 99% of infections in humans and warm-blooded animals.[14] This subspecies is further divided into over 2,600 serovars (or serotypes), with fewer than 100 linked to disease in humans.[13] These serovars can also be classified into typhoidal and non-typhoidal serovars. Typhoidal serovars are host-specific and primarily infect humans, whereas non-typhoidal serovars have a broad host range and are recognized for their ability to infect both animals and people. NARMS monitors antibiotic resistance patterns in non-typhoidal *S. enterica* isolates collected from livestock at slaughter. **Table 3** below presents the top 10 *Salmonella* serovars identified in the NARMS dataset for all animal species slaughtered in California combined. This data is further broken down by animal classes in **Tables 4 through 7**. Although NARMS collects serovar-level AST data, for the purpose of this pathogen-specific report, resistant isolate results are presented for all *Salmonella* serovars combined within each host animal class. Serovar-specific resistant isolate data will be included in future AUS resources, such as animal species-specific reports and dashboards.

Table 3. Total Salmonella Serovars Identified by NARMS Across All Animal Classes in California-Slaughtered Food Animals, 2014-2023.

Serotype	Rank	Isolates N = 802*	%
Montevideo	1	164	20.45
Anatum	2	65	8.10
Typhimurium	3	54	6.73
Kentucky	4	47	5.86
Infantis	5	33	4.11
Senftenberg	6	32	3.99
Newport	7	30	3.74
Johannesburg	8	28	3.49
Muenchen	8	28	3.49
Cerro	9	26	3.24
Derby	10	25	3.12
Others below top 10		270	33.67

* Represents total number of California isolates, including those from bob veal, lamb, and sheep, which are not included in this report.

Table 4. Total Salmonella Serovars Identified by NARMS in California-Slaughtered Cattle, 2014-2023.

Serotype	Rank	Isolates N = 373	%
Montevideo	1	139	37.27
Typhimurium	2	31	8.31
Newport	3	28	7.51
Muenchen	4	19	5.09
Anatum	5	17	4.56
Cerro	6	15	4.02
Muenster	7	14	3.75
Altona	8	9	2.41
Mbandaka	8	9	2.41
I 4,[5],12:i:-	9	8	2.14
Senftenberg	9	8	2.14
Others below top 10		76	20.38

Table 5. Total Salmonella Serovars Identified by NARMS in California-Slaughtered Chickens, 2014-2023.

Serotype	Rank	Isolates N = 74	%
Kentucky	1	40	54.05
Enteritidis	2	10	13.51
Infantis	3	8	10.81
Typhimurium	4	5	6.76
Alachua	5	2	2.70
Hadar	5	2	2.70
Anatum	6	1	1.35
Braenderup	6	1	1.35
I 4,[5],12:i:-	6	1	1.35
Johannesburg	6	1	1.35
Ohio	6	1	1.35
Ouakam	6	1	1.35
Rissen	6	1	1.35

Table 6. Total Salmonella Serovars Identified by NARMS in California-Slaughtered Turkeys, 2014-2023.

Serotype	Rank	Isolates N = 23	%
Schwarzengrund	1	4	17.39
Hadar	2	3	13.04
I 4,[5],12:i:-	2	3	13.04
Senftenberg	2	3	13.04
Indiana	3	2	8.70
Kentucky	3	2	8.70
Anatum	4	1	4.35
Derby	4	1	4.35
Heidelberg	4	1	4.35
Infantis	4	1	4.35
Montevideo	4	1	4.35
Muenster	4	1	4.35

Table 7. Total Salmonella Serovars Identified by NARMS in California-Slaughtered Swine, 2014-2023.

Serotype	Rank	Isolates N = 280	%
Anatum	1	46	16.43
Johannesburg	2	26	9.29
Derby	3	22	7.86
Senftenberg	4	21	7.50
Infantis	5	20	7.14
Eko	6	19	6.79
Typhimurium	7	16	5.71
Brandenburg	8	10	3.57
Reading	9	8	2.86
Adelaide	10	7	2.50
Cerro	10	7	2.50
London	10	7	2.50
Others below top 10		71	25.36

Trends in Resistance and Reduced Susceptibility to Antibiotics Using AST

Cattle

Figure 1 displays the percentage of *Salmonella* isolates that underwent AST, from screened NARMS cecal samples collected from cattle slaughtered in California and categorized as resistant to the antibiotics included in the NARMS AST panel by year. Between 2014 and 2017 the number (N) of isolates that underwent AST was below the CLSI-recommended threshold of 30, preventing interpretations for these years. However, the percentage of resistant isolates in relation to all antibiotics tested has remained below 10% from 2018 to 2023.

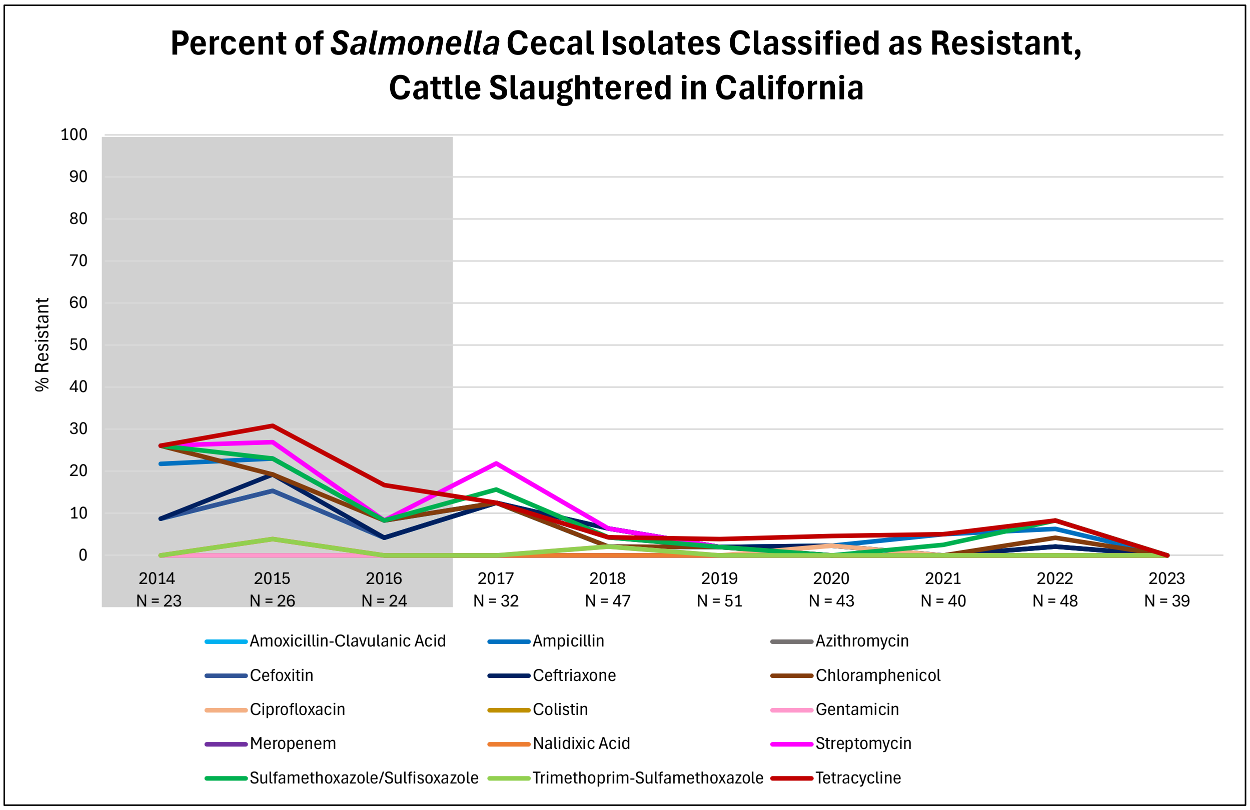


Figure 1. Data Trends in the Percent Resistant Salmonella Isolates from Cattle Slaughtered in California, NARMS Cecal Isolates Tested with the NARMS Antibiotic Panel, 2014-2023.

N indicates the number of isolates tested in a given year. Years and sample numbers shaded in gray indicate less than 30 isolates; therefore, these numbers should be interpreted with caution and are not considered representative of the broader population of cattle raised or slaughtered in California.

The percentage of resistant isolates for screened NARMS cecal samples collected from cattle slaughtered in California that underwent AST for *Salmonella* is displayed as a heat map in **Figure 2**. For this and all subsequent heat maps, antibiotics are listed on the y-axis, and the years of sample collection are on the x-axis. The color of each cell represents the percentage of isolates classified as resistant: blue shades represent a lower percentage of resistant isolates, while red shades represent a higher percentage of resistant isolates. Darker red shades show the highest percentage of resistant isolates. The number inside each cell represents the exact percentage of resistant isolates, making it easier to identify broad trends in susceptibility over time and compare deviations in resistant isolates across different drugs. The interpretation of the heat map for *Salmonella* in California-slaughtered cattle is the same as **Figure 1.**

Heat Map of Percent Resistant *Salmonella* in NARMS Cecal Isolates, Cattle Slaughtered in California, 2014-2023

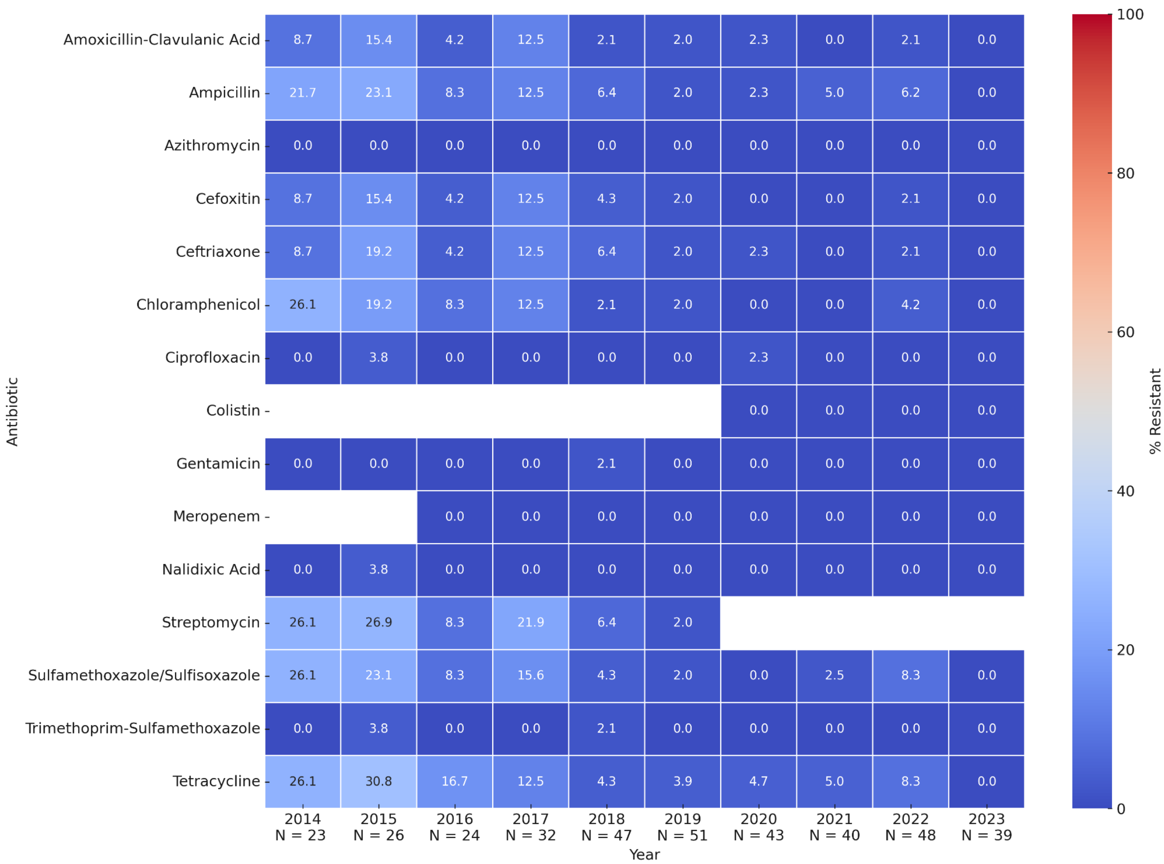


Figure 2. Heat Map Displaying Trends in the Percent Resistant Salmonella Isolates from Cattle Slaughtered in California, NARMS Cecal Isolates Tested with the NARMS Antibiotic Panel, 2014-2023. N indicates the number of isolates tested in a given year.

Chickens

The percentage of *Salmonella* isolates from screened NARMS cecal samples collected from chickens slaughtered in California that were classified as resistant in relation to the antibiotics included in the NARMS AST panel by year is displayed in **Figures 3 and 4.** Since the number (N) of bacterial isolates that underwent AST each year is below the CLSI-recommended threshold of 30 isolates, meaningful trends in susceptibility for all years in this dataset cannot be determined. As such, an interpretation of the broader chicken cecal data across California cannot be provided.

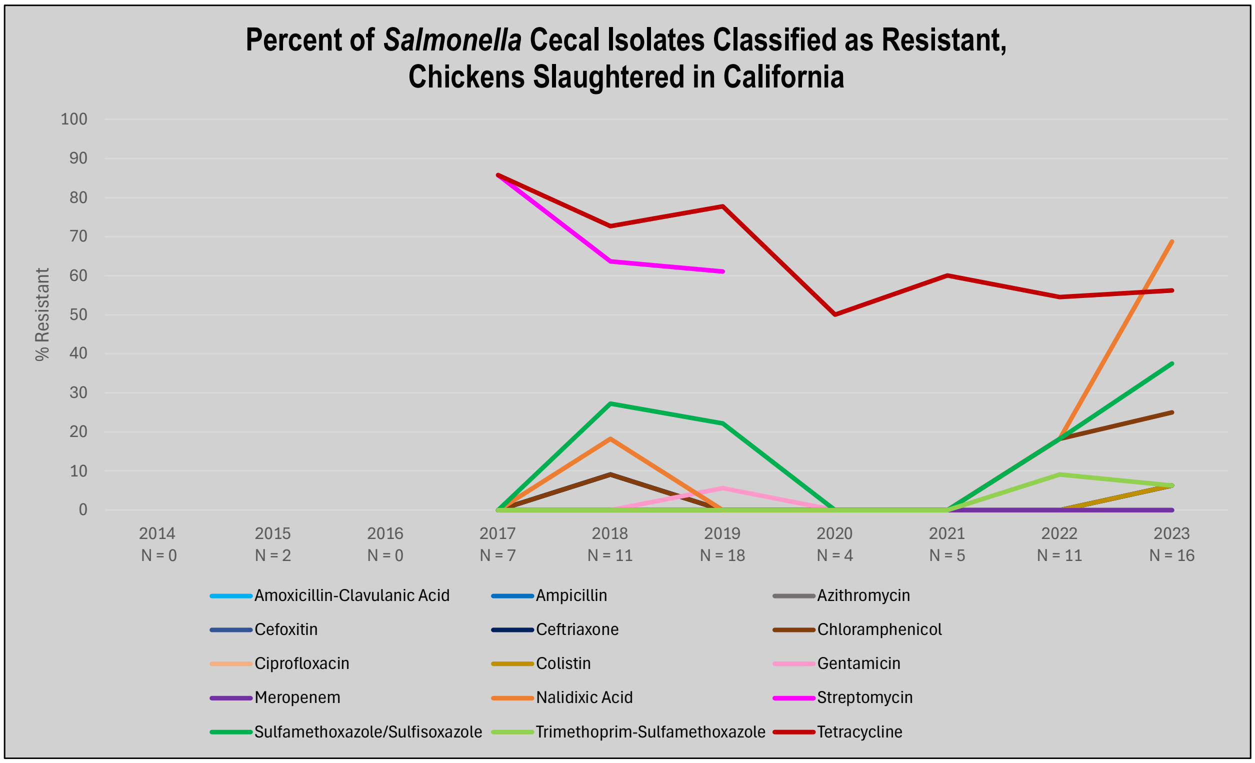


Figure 3. Trends in the Percent Resistant Salmonella Isolates from Chickens Slaughtered in California, NARMS Cecal Isolates Tested with the NARMS Antibiotic Panel, 2014-2023.

N indicates the number of isolates tested in a given year. Data from the two isolates tested in 2015 are not shown in this figure, as there were no isolates tested in the year before or after; data from the two 2015 isolates are included in Figure 4. Years and sample numbers shaded in gray indicate less than 30 isolates; therefore, these numbers should be interpreted with caution and are not considered representative of the broader population of chickens raised or slaughtered in California.

Heat Map of Percent Resistant *Salmonella* in NARMS Cecal Isolates, Chickens Slaughtered in California, 2014-2023

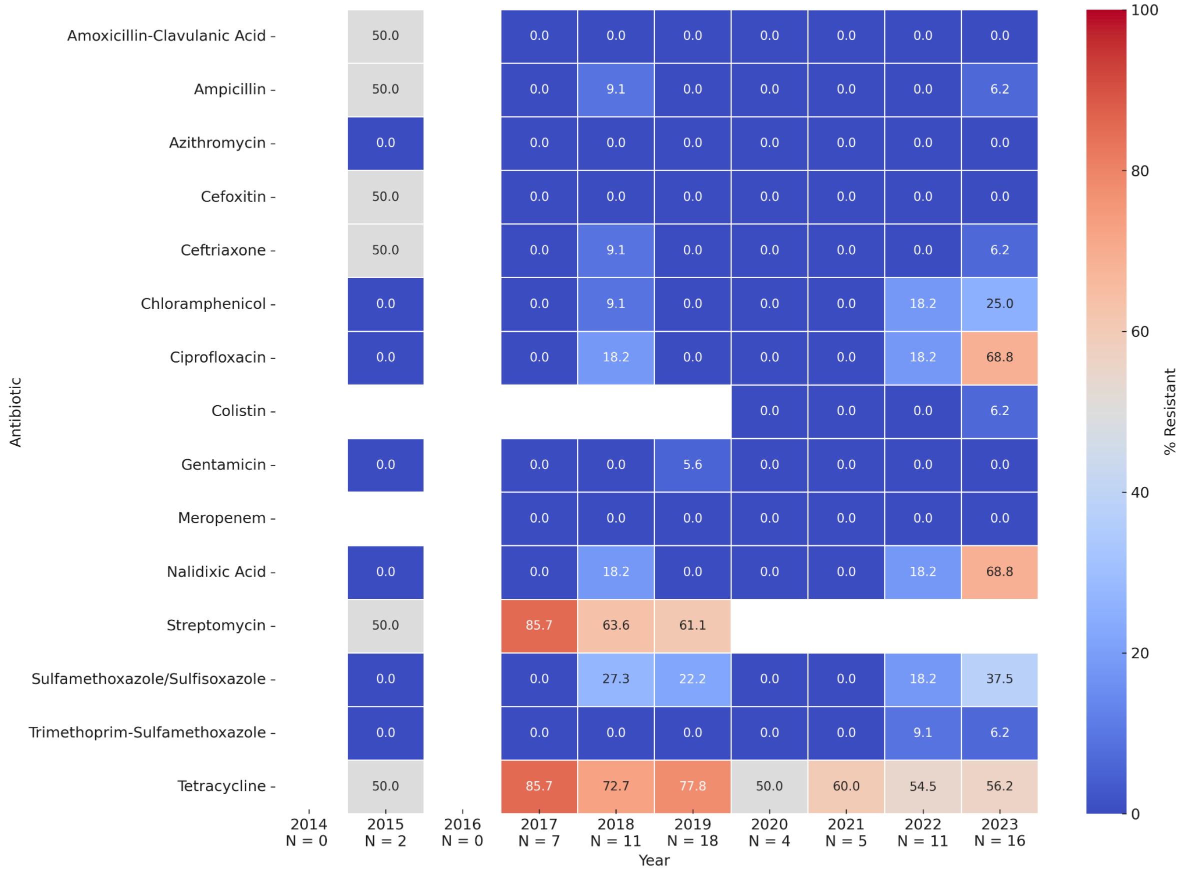


Figure 4. Heat Map Displaying Trends in the Percent Resistant Salmonella Isolates in Chickens Slaughtered in California, NARMS Cecal Isolates tested with the NARMS Antibiotic Panel, 2014-2023.
N indicates the number of isolates tested in a given year. Since less than 30 isolates were tested yearly, these numbers should be interpreted with caution and are not considered representative of the broader population of chickens raised or slaughtered in California.

Turkeys

The percentage of all species of *Salmonella* isolates from screened NARMS turkey cecal samples that underwent AST and were classified as resistant in relation to the antibiotics included in the NARMS AST panel by year is displayed in **Figures 5 and 6.** Since the number (N) of bacterial isolates that underwent AST per year is below the CLSI-recommended threshold of 30 isolates, meaningful trends in susceptibility for all years in this dataset cannot be determined. As such, an interpretation of the broader turkey cecal data across California cannot be provided.

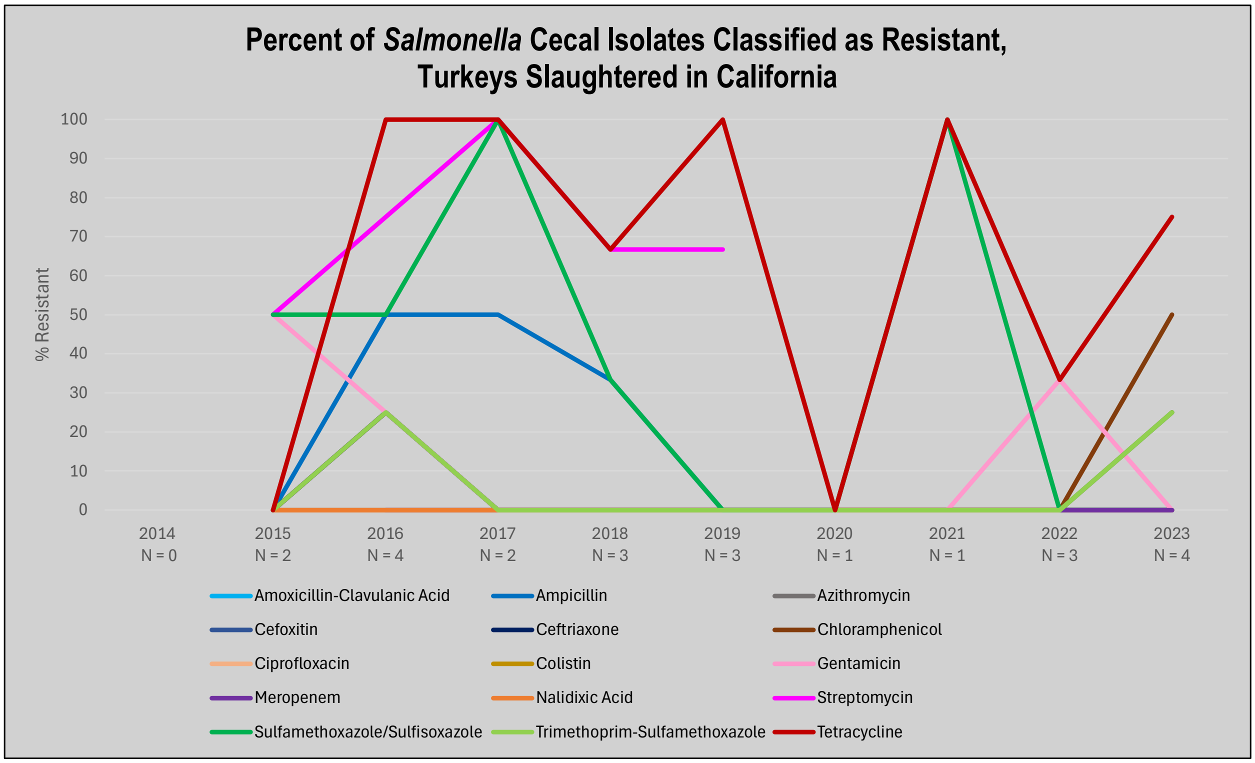


Figure 5. Trends in the Percent Resistant Salmonella Isolates from Turkeys Slaughtered in California, NARMS Cecal Isolates Tested with the NARMS Antibiotic Panel, 2014-2023.

N indicates the number of isolates tested in a given year. Years and sample numbers shaded in gray indicate less than 30 isolates; therefore, these numbers should be interpreted with caution and are not considered representative of the broader population of turkeys raised or slaughtered in California.

Heat Map of Percent Resistant *Salmonella* in NARMS Cecal Isolates, Turkeys Slaughtered in California, 2014-2023

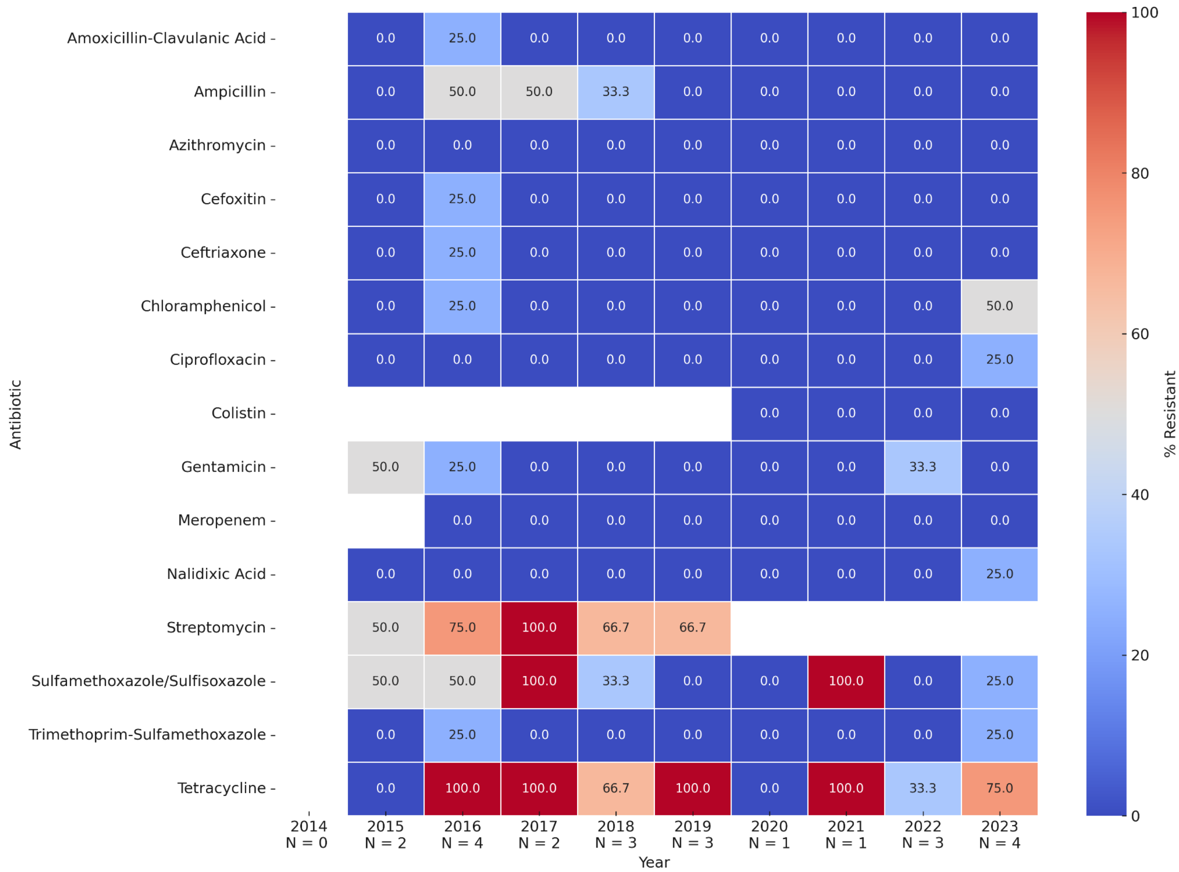


Figure 6. Heat Map Displaying Trends in the Percent Resistant Salmonella Isolates in Turkeys Slaughtered in California, NARMS Cecal Isolates Tested with the NARMS Antibiotic Panel, 2014-2023. N indicates the number of isolates tested in a given year. Since less than 30 isolates were tested yearly, these numbers should be interpreted with caution and are not considered representative of the broader population of turkeys raised or slaughtered in California.

Swine

The percentage of *Salmonella* isolates from screened NARMS cecal samples collected from swine slaughtered in California that were classified as resistant in relation to the antibiotics included in the NARMS AST panel by year is displayed in **Figures 7 and 8**. Data reported from 2014 and between 2016 and 2019 indicate a relatively stable percentage of resistant isolates or a decreasing percentage, as for tetracycline and sulfamethoxazole/sulfisoxazole. For the remaining years, the number (N) of bacterial isolates that underwent AST is below the CLSI-recommended threshold of 30 isolates, preventing interpretations for these years.

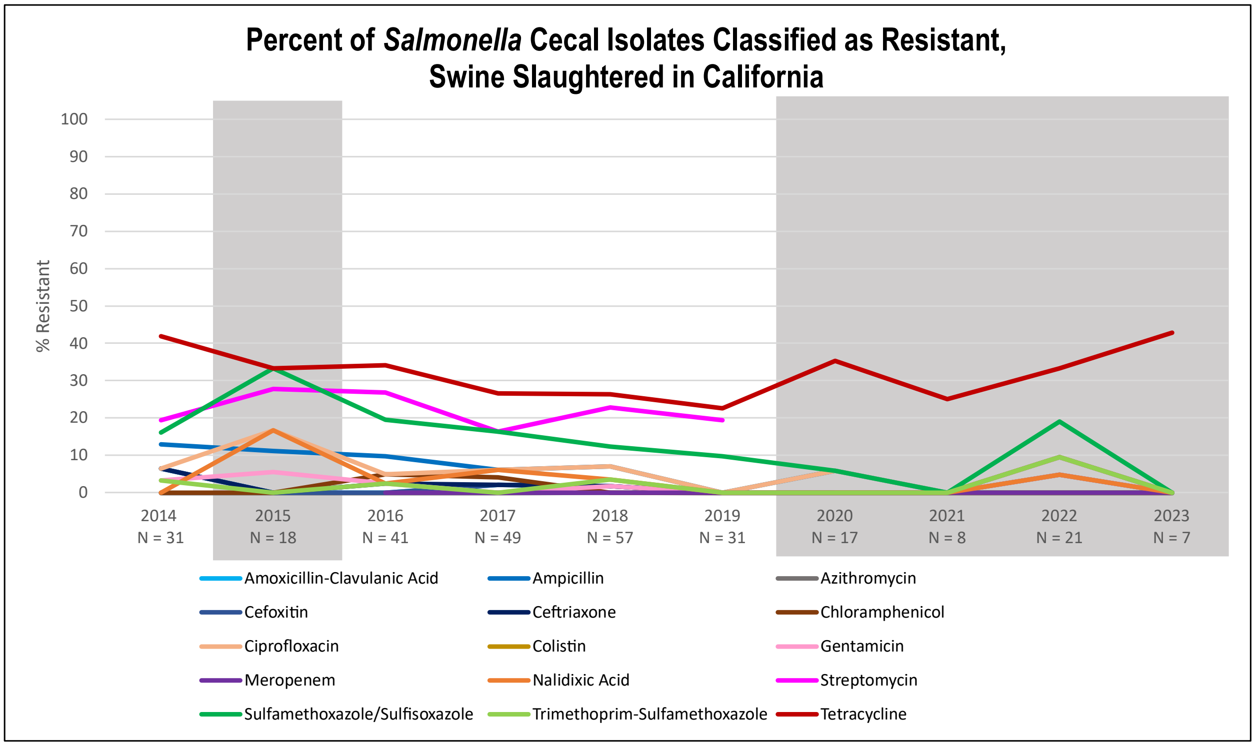


Figure 7. Trends in the Percent Resistant Salmonella Isolates from Swine Slaughtered in California, NARMS Cecal Isolates Tested with the NARMS Antibiotic Panel, 2014-2023.

N indicates the number of isolates tested in a given year. Years and sample numbers shaded in gray indicate less than 30 isolates; therefore, these numbers should be interpreted with caution and are not considered representative of the broader population of swine raised or slaughtered in California.

Heat Map of Percent Resistant *Salmonella* in NARMS Cecal Isolates, Swine Slaughtered in California, 2014-2023

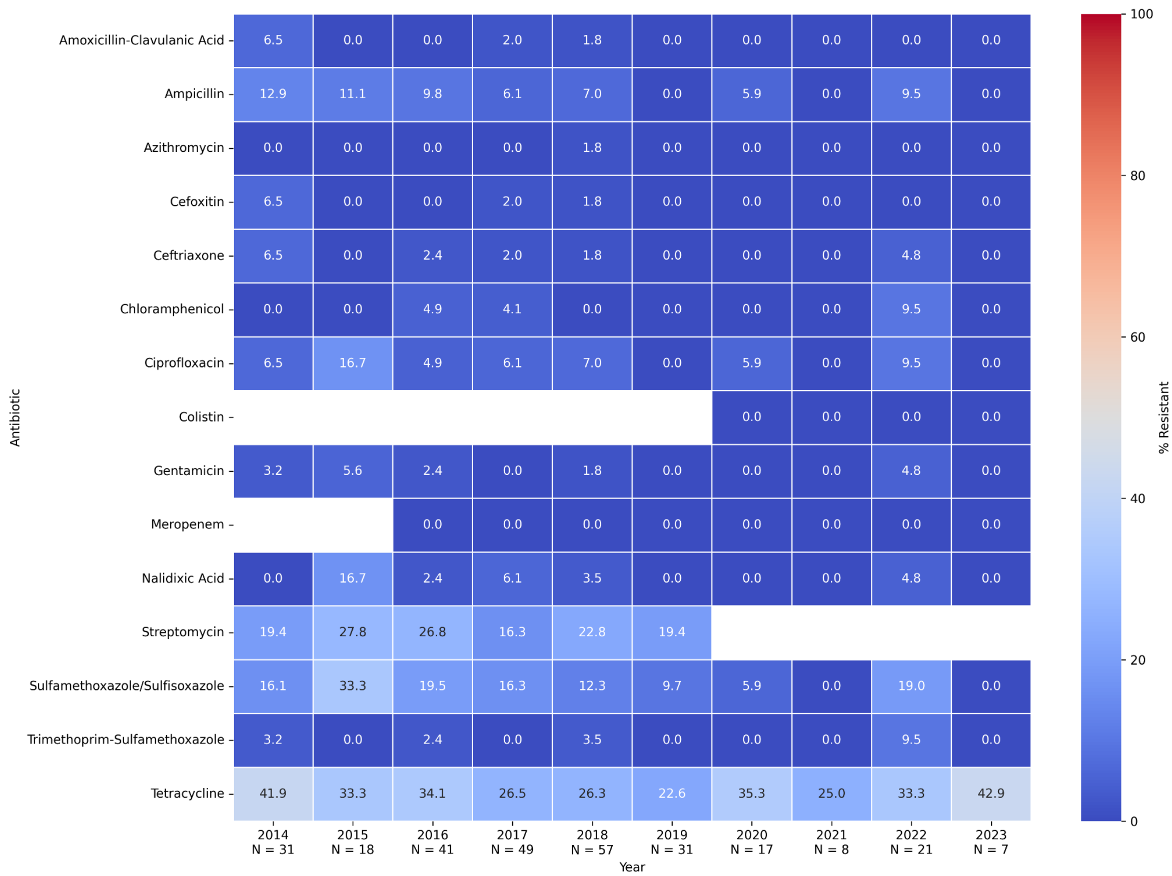
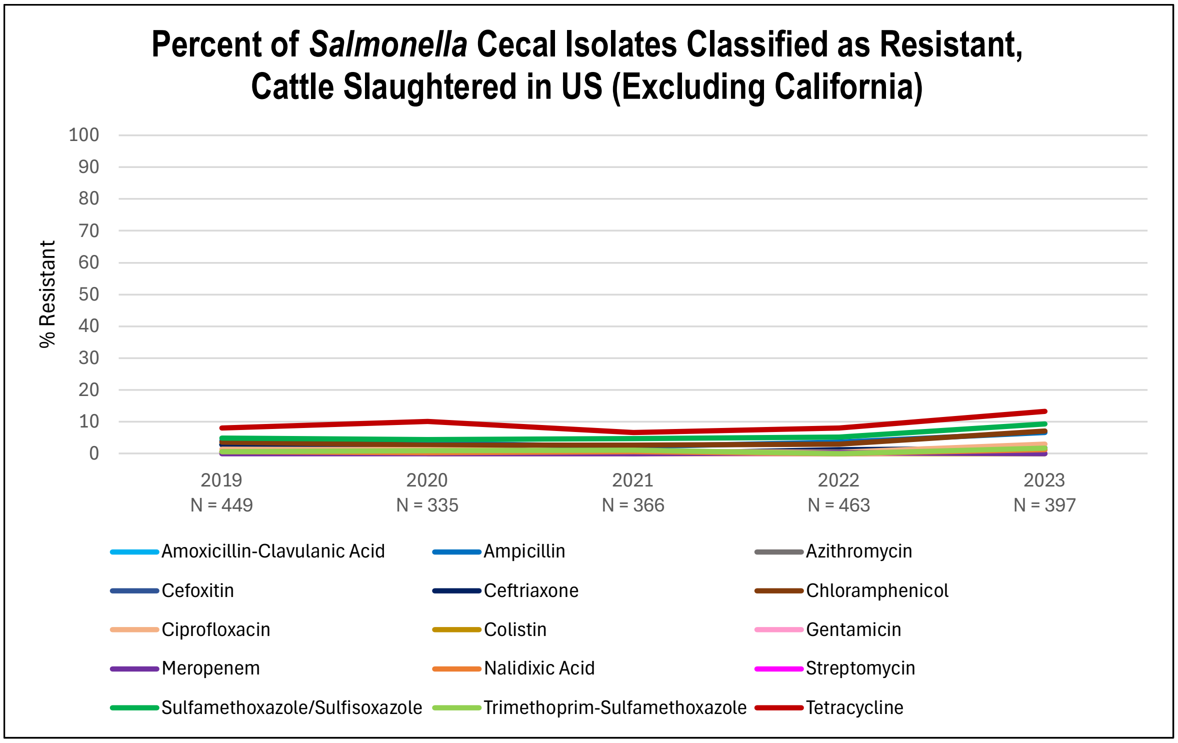


Figure 8. Heat Map Displaying Trends in the Percent Resistant Salmonella Isolates in Swine Slaughtered in California, NARMS Cecal Isolates Tested with the NARMS Antibiotic Panel, 2014-2023. N indicates the number of isolates tested in a given year. Since less than 30 isolates were tested yearly after 2019, these numbers should be interpreted with caution and are not considered representative of the broader population of swine raised or slaughtered in California.

Comparison of California-Specific Antibiotic Susceptibility Trends to Other NARMS-Participating States

Data across all NARMS-participating states was obtained from the NARMS Now Integrated Data portal.[8] Below, trends in the percentage of resistant NARMS *Salmonella* cecal isolates from cattle slaughtered in California are compared side-by-side with cattle data from all other states contributing to the NARMS Cecal Sampling Program (excluding California data) for antibiotics available in the NARMS Now Integrated Data portal from 2019-2023. To further illustrate California's alignment or divergence from trends in resistant isolates observed in cattle from other states participating in the NARMS Cecal Sampling Program, we present a heat map. Although national data (excluding California) for NARMS *Salmonella* cecal isolates from chickens, turkeys, and swine are displayed below, side-by-side comparisons with California-specific data and heat maps are not provided due to the limited number of yearly isolates from California, which hinders meaningful interpretation.

Figure 9 shows that the percentage of antibiotic-resistant *Salmonella* isolates from NARMS cecal samples collected from cattle slaughtered nationwide (excluding California) and in California has remained below 20% and 10%, respectively, across all years for the antibiotics tested. In 2023, the percentage of resistant isolates in California, although already low, decreased to 0% for all antibiotics tested. In fact, this is true for the percentage of resistant isolates for five antibiotics classified as “critically important” (see **Appendix C**), including azithromycin, colistin, meropenem, gentamicin, and trimethoprim-sulfamethoxazole. In contrast, a marginal increase for some antibiotics, including tetracycline, sulfamethoxazole/sulfisoxazole, and chloramphenicol, was observed in 2023 for other participating states.



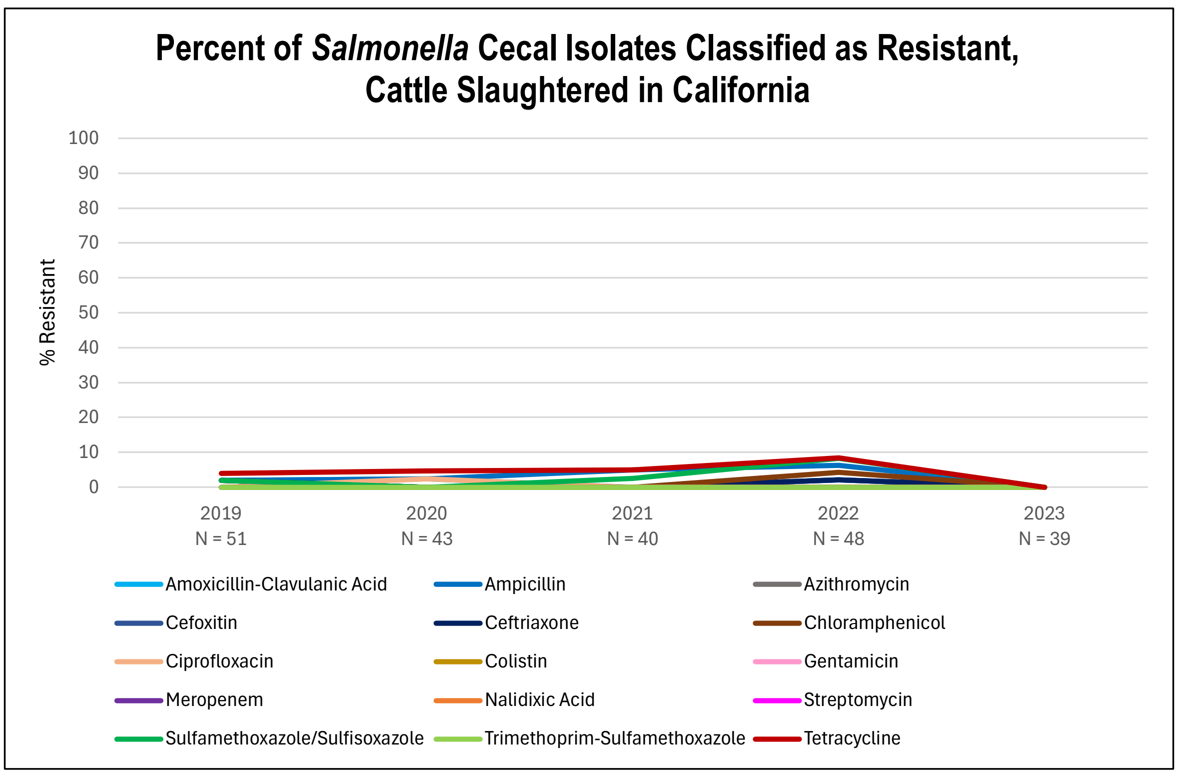


Figure 9. Comparison of Trends in the Percent Resistant Salmonella Isolates from US NARMS Cattle Data (Excluding California) and Cattle Slaughtered in California Data, NARMS Cecal Isolates Tested with the NARMS Antibiotic Panel, 2019-2023.

N indicates the number of isolates tested in a given year.

Figure 10 is a heat map comparison of NARMS cecal *Salmonella* isolates from cattle. This comparison graph illustrates the differences in the percentage of resistant NARMS *Salmonella* isolates to the NARMS antibiotic panel in California-slaughtered food animals versus all other participating states, by year. Red tones or positive differences indicate a higher percentage of resistant isolates in California-slaughtered cattle isolates, while blue tones or negative differences reflect a lower percentage of resistant isolates in California-slaughtered cattle isolates compared to other states participating in the NARMS program.

Heat Map of Percent Resistant Difference in *Salmonella* NARMS Cecal Isolates, Cattle Slaughtered in California vs. US NARMS Data (Excluding CA), 2019-2023

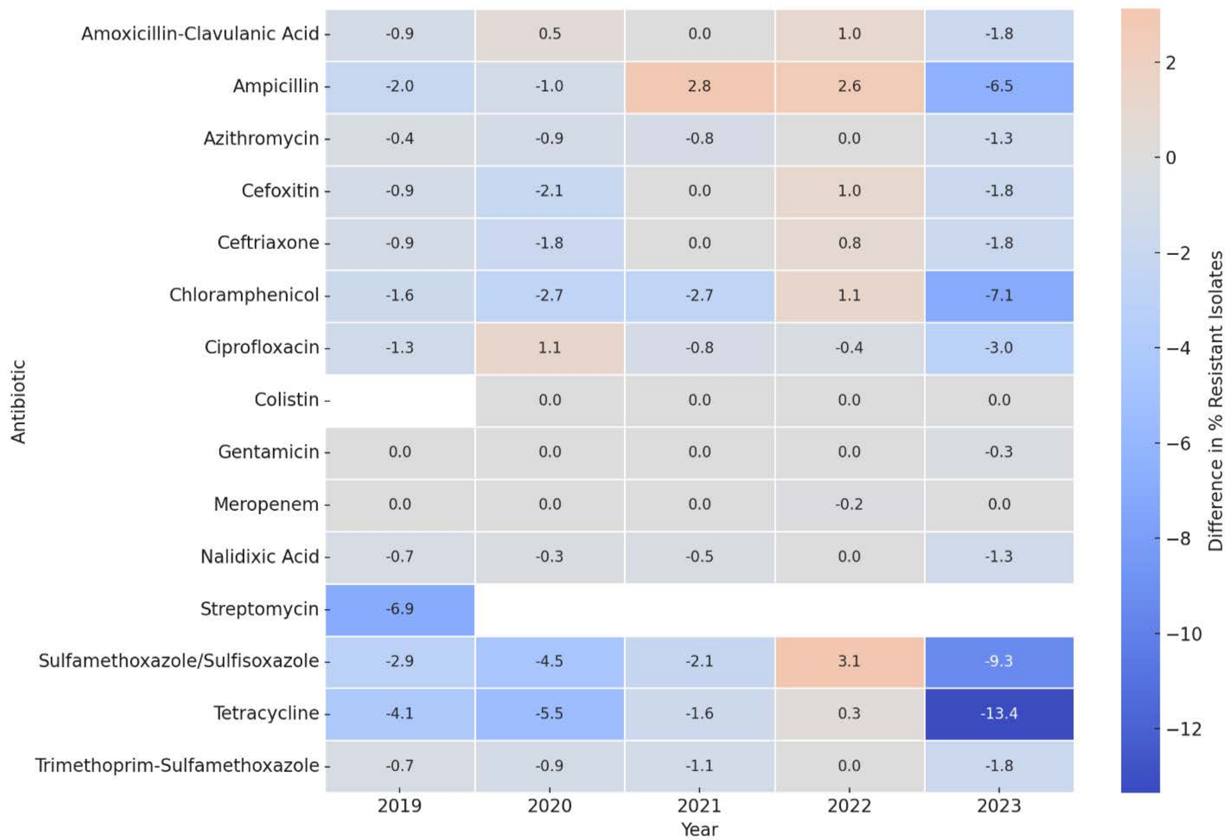


Figure 10. Heat Map of the Difference of the Percent Resistant Salmonella Isolates from US NARMS Cattle Data (Excluding California) and Cattle Slaughtered in California Data, NARMS Cecal Isolates Tested with the NARMS Antibiotic Panel, 2019-2023.

The percentage of resistant *Salmonella* isolate data for chickens, turkeys, and swine slaughtered in other states participating in the NARMS program, excluding California, are presented in **Figures 11, 12, and 13**. However, the number of California-specific bacterial isolates that underwent AST per year for these species remained below the recommended threshold of 30 isolates necessary to compare trends in the percentage of resistant isolates. As a result, side-by-side comparison and the interpretation of these data cannot be provided.

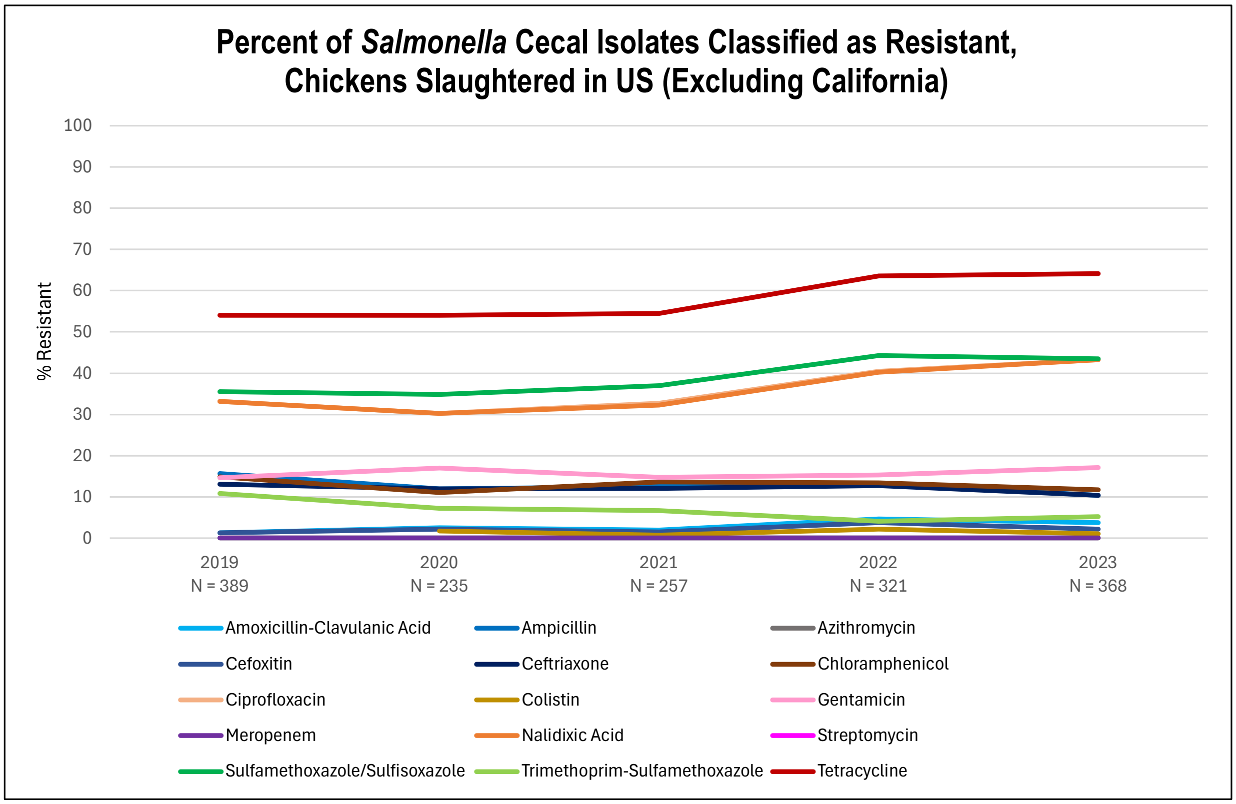


Figure 11. The Percent Resistant Salmonella Isolates in Chickens, US NARMS Data (Excluding California), Cecal Isolates, 2019-2023.

N indicates the number of isolates tested in a given year.

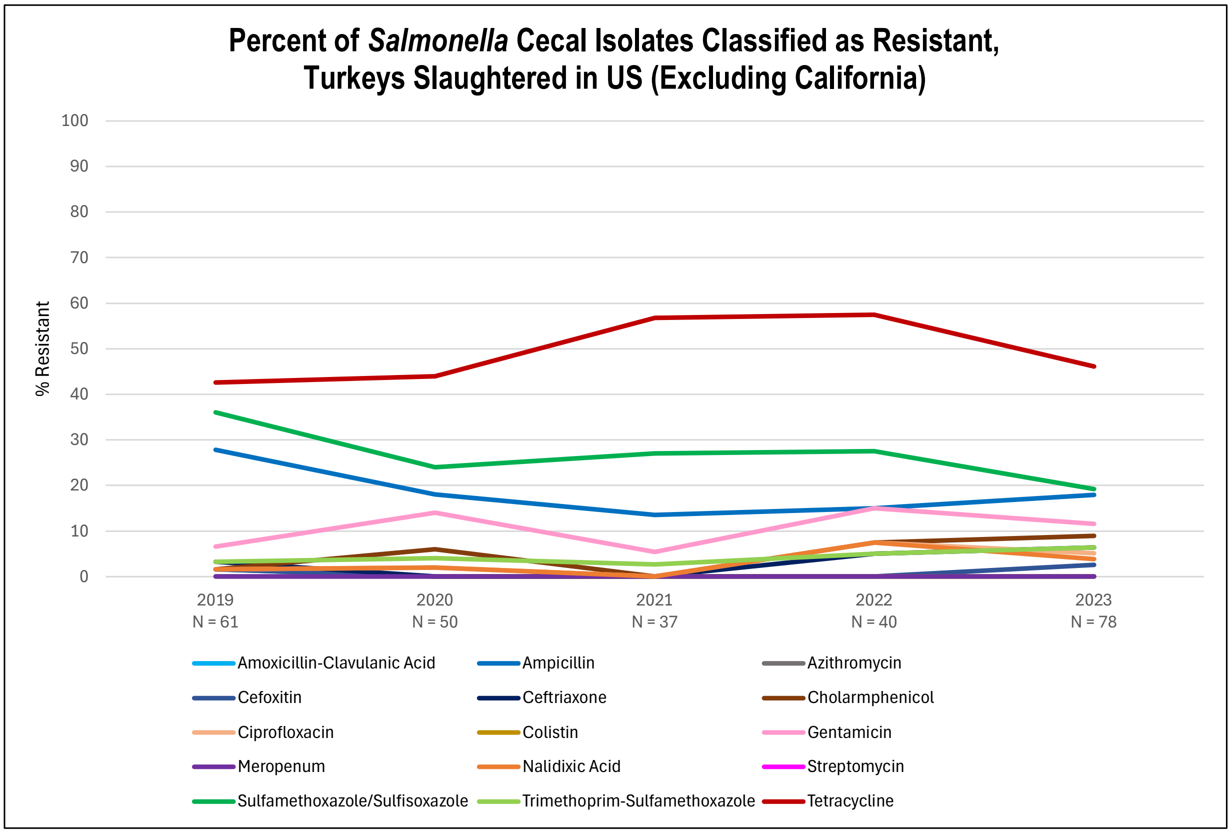


Figure 12. The Percent Resistant Salmonella Isolates in Turkeys, US NARMS Data (Excluding California), Cecal Isolates, 2019-2023.

N indicates the number of isolates tested in a given year.

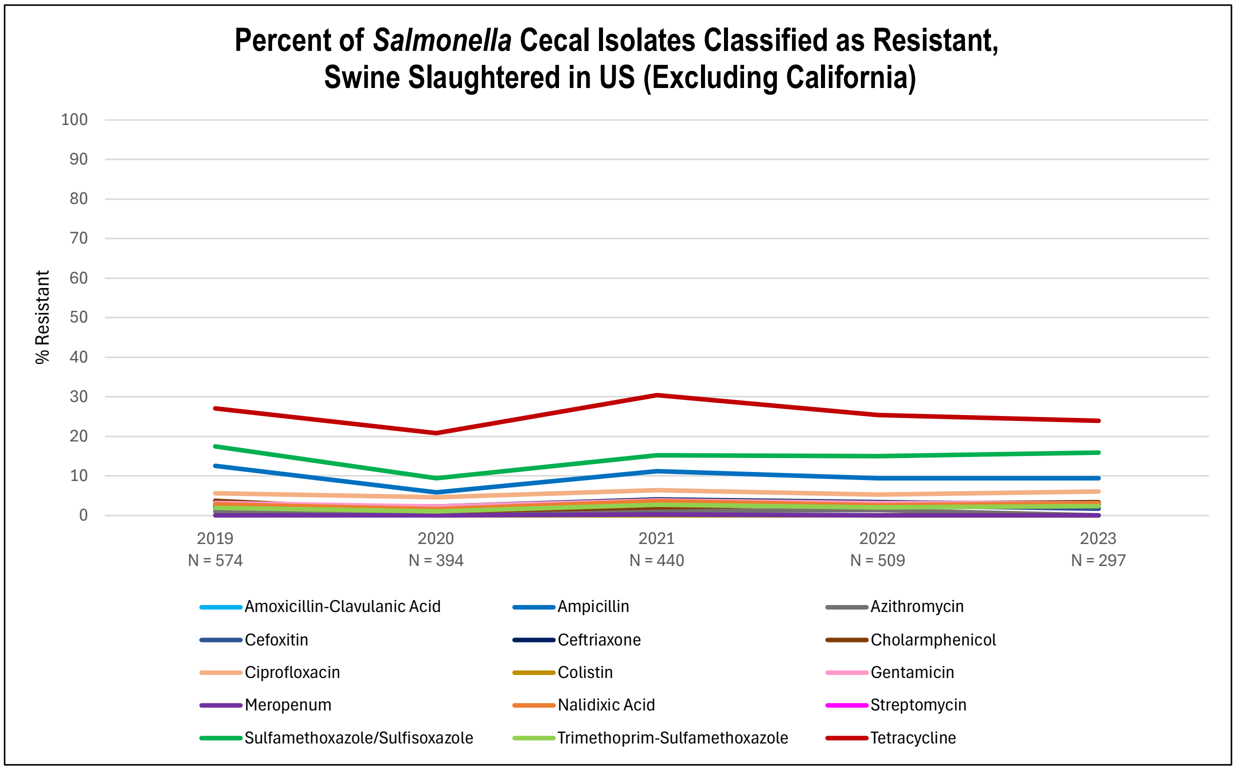


Figure 13. The Percent Resistant Salmonella Isolates in Swine, US NARMS Data (Excluding California), Cecal Isolates, 2019-2023.

N indicates the number of isolates tested in a given year.

Future Directions

NARMS continues to expand its usage of WGS to predict antimicrobial resistance profiles and has transitioned toward using WGS to predict antimicrobial susceptibility in most non-cecal isolates, moving away from traditional phenotypic AST.[20] As a result, future NARMS reports may present susceptibility data based on genomic prediction models rather than interpretations of laboratory-derived MICs. This shift may lead to changes in how susceptibility classifications are reported, potentially affecting trend comparisons over time.

In the future, AUS plans to provide updated, California-specific information from NARMS for *Campylobacter, Salmonella*, *E. coli*, and *Enterococcus* cecal isolates obtained in California. The format, specific content, and frequency may differ by pathogen due to variations in NARMS AST methodology and interpretive criteria, and the number of isolates obtained from California over time. AUS also intends to release a cattle-focused report that will include data on all four enteric pathogens monitored in the NARMS dataset. Additionally, AUS will continue to explore the application of epidemiologic cut-off values to the AST data, if and where the data allow, to focus on changes in the bacterial populations rather than human clinical efficacy. Finally, AUS is committed to overcoming the inherent challenges of static reports and is actively exploring innovative solutions to provide stakeholders with an interactive dashboard. This user-driven experience will ensure that all data is easily accessible and readily available, empowering our stakeholders to make informed and timely decisions.

Acknowledgements

CDFA AUS would like to thank USDA FSIS and NARMS for providing access to these valuable data specific to California and general consultation on the dataset organization and NARMS program procedures.

Appendix A

Table A1: Antimicrobial Agents and Antimicrobial Susceptibility Testing Methods for *Salmonella* Isolates, 1996-2024.[21]

	Method	Broth Microdilution										
	Sensititre® Plate Name	CMV1CCDC[2] / CMV3CNCD	CMV3CNCD	CMV4CNCD	CMV5CNCD	CMV6CNCD	CMV7CNCD	CMV1AGNF	CMV2AGNF	CMV3AGNF	CMV4AGNF	CMV5AGNF
	Year[1]	1996	1997-1998	1999	2000	2001	2002-2003	2004-2010	2011-2012	2013-2015	2016-2019	2020-Current
Antimicrobial Class	**Antimicrobial Agent**											
Aminocyclitols	Apramycin	√	√	√	√	√						
Aminoglycosides	Amikacin		√	√	√	√	√	√				
	Gentamicin	√	√	√	√	√	√	√	√	√	√	√
	Kanamycin	√	√	√	√	√	√	√	√			
	Streptomycin	√	√	√	√	√	√	√	√	√	√	
Carbapenems	Meropenem										√	√
β-Lactam/β-Lactamase Inhibitor Combinations	Amoxicillin–Clavulanic Acid	√	√	√	√	√	√	√	√	√	√	√
Cephems	Cefoxitin				√	√	√	√	√	√	√	√
	Ceftiofur	√	√	√	√	√	√	√	√	√		
	Ceftriaxone	√	√	√	√	√	√	√	√	√	√	√
	Cephalothin	√	√	√	√	√	√					
Coumarins	Novobiocin	√										
Folate Pathway Inhibitors	Sulfamethoxazole	√	√	√	√	√	√					
	Sulfisoxazole							√	√	√	√	√
	Trimethoprim–Sulfamethoxazole	√	√	√	√	√	√	√	√	√	√	√
Macrolides	Azithromycin								√	√	√	√
Penems	Imipenem					√						
Penicillins	Ampicillin	√	√	√	√	√	√	√	√	√	√	√
	Ticarcillin		√									
Phenicols	Chloramphenicol	√	√	√	√	√	√	√	√	√	√	√
	Florfenicol			√								
Polymyxin	Colistin											√
Quinolones	Ciprofloxacin	√	√	√	√	√	√	√	√	√	√	√
	Nalidixic acid	√	√	√	√	√	√	√	√	√	√	√
Tetracyclines	Tetracycline	√	√	√	√	√	√	√	√	√	√	√

[1] Testing of *Salmonella* isolates from humans, food animals, and retail meats began in 1996, 1997, and 2002, respectively

[2] In 1996, most isolates were tested using Sensititre® plate CMV1CCDC, but a few isolates were tested using Sensititre® plate CMV3CNCD

Appendix B

Table B1. Interpretive Criteria Used for Susceptibility Testing of *Salmonella*.[21]

Antimicrobial Class	Antimicrobial Agent	Profile Abbreviation	Breakpoints (µg/ml)[1]		
			Susceptible	Intermediate	Resistant
Aminoglycosides	Gentamicin	Gen	≤ 4	8	≥ 16
	Streptomycin	Str	≤ 16	N/A	≥ 32
β-Lactam/β-Lactamase Inhibitor Combinations	Amoxicillin–Clavulanic Acid	Aug	≤ 8 / 4	16 / 8	≥ 32 / 16
Carbapenems	Meropenem	Mer	≤ 1	2	≥ 4
Cephems	Cefoxitin	Fox	≤ 8	16	≥ 32
	Ceftriaxone	Axo	≤ 1	2	≥ 4
Folate Pathway Inhibitors	Sulfamethoxazole/ Sulfisoxazole[2]	Fis	≤ 256	N/A	≥ 512
	Trimethoprim–Sulfamethoxazole	Cot	≤ 2 / 38	N/A	≥ 4 / 76
Macrolides	Azithromycin	Azi	≤ 16	N/A	≥ 32
Penicillins	Ampicillin	Amp	≤ 8	16	≥ 32
Phenicols	Chloramphenicol	Chl	≤ 8	16	≥ 32
Polymyxin	Colistin	Col	N/A	≤ 2	≥ 4
Quinolones	Ciprofloxacin[3]	Cip	≤ 0.06	0.12-0.5	≥1
	Nalidixic acid	Nal	≤ 16	N/A	≥ 32
Tetracyclines	Tetracycline	Tet	≤ 4	8	≥ 16

[1] Breakpoints were adopted from CLSI (Clinical and Laboratory Standards Institute) M100-S22 document, except for streptomycin and azithromycin which have no CLSI breakpoints.

[2] Sulfamethoxazole was tested from 1996 through 2003 and was replaced by sulfisoxazole in 2004.

[3] In 2012, the Clinical and Laboratory Standards Institute (CLSI)'s M100-S27 expanded the Minimum Inhibitory Concentration (MIC) range that defines the intermediate susceptibility category for ciprofloxacin. We now use decreased susceptibility to ciprofloxacin (DSC, MIC >= 0.12 ug/ml) as a marker for emerging fluoroquinolone resistance (CLSI, 2017)

Appendix C

Table C1. NARMS *Salmonella* AST Panel and Uses in Food Animals.

Antimicrobial Class	Antimicrobial Formulation	FDA GFI 152 Classification	Human or Food Animal Use	Approved Animal Use
Aminoglycosides	Gentamicin	Critically Important	Both	Water (swine), Oral Solution (swine), IM (swine), SC (swine, chickens, turkeys), OU (calves)
	Streptomycin	Critically Important	Both	Water (calves, chickens, swine), Alternative Formulation: IM (cattle, swine)
β-Lactam/β-Lactamase Inhibitor Combinations	Amoxicillin-Clavulanic Acid	Highly Important	Humans	Not approved for use in food animals
Carbapenems	Meropenem	Critically Important	Human	Not approved for use in food animals
Cephems	Cefoxitin	Highly Important	Humans	Not approved for use in food animals
	Ceftriaxone	Critically Important	Humans	Not approved for use in food animals
Folate Pathway Inhibitors	Sulfamethoxazole/ Sulfisoxazole	Not Classified	Both	Alternative Formulations: IV (cattle), PO (cattle, calves), Feed (chickens, turkeys), Water (cattle, swine, chickens, turkeys), Milk (calves)
	Trimethoprim-Sulfamethoxazole	Critically Important	Humans	Not approved for use in food animals
Macrolides	Azithromycin	Critically Important	Humans	Not approved for use in food animals
Penicillins	Ampicillin	Critically Important	Both	IM (cattle, swine), IMM (cattle), PO (calves)
Phenicols	Chloramphenicol	Highly Important	Humans	Not approved for use in food animals
Polymyxin	Colistin	Critically Important	Humans	Not approved for use in food animals
Quinolones	Ciprofloxacin	Critically Important	Humans	Not approved for use in food animals
	Nalidixic acid	Important	Humans	Not approved for use in food animals
Tetracycline	Tetracycline	Highly Important	Both	Alternative Formulation: Feed (cattle, swine, chickens, turkeys), Water (cattle, swine, chickens, turkey), IM (cattle, swine), PO (cattle), TOP (cattle, swine)

*Antibiotics above are those included in the NARMS antibiotic panel for *Salmonella* AST. Food animal approved use of these drugs and other drug formulations within the antibiotic class approved for use in food animals are listed. Classification of these drugs under GFI #152 is listed.

Feed: medicated feed
Water: medicated water
PO: oral bolus
IM: intramuscular
IV: intravenous

SC: subcutaneous
SCi: subcutaneous implant
TOP: topical
OU: ocular
AU: otic

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