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

Prepared by:

California Department of Food and Agriculture
Antimicrobial Use and Stewardship Program
October 2025

Suggested citation:

California Department of Food and Agriculture. Antimicrobial Use and Stewardship Program. (2025). CDFA AUS Multi-Year Report on the California-Specific NARMS Data—2014-2023: *Escherichia coli*

To access this report online: https://www.cdfa.ca.gov/ahfss/AUS/

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.

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

Introduction

Antibiotics are life-saving drugs vital to protect people and animals from bacterial infections. Antibiotic resistance occurs when bacteria evolve, rendering the 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 evident in a high percentage of human foodborne illness cases associated with antibiotic-resistant bacteria, leading to 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] Some bacteria are monitored not only because they cause foodborne illness, but also because they serve as indicator bacteria to monitor environmental contamination, adherence to food safety performance standards, track emerging resistance patterns, and estimate risks to human and animal health.[8-10] Indicator bacteria serve as an early warning sign that can signal the onset and potential spread of antibiotic resistance.[11] By closely observing and monitoring emerging resistance patterns in these indicator bacteria, it is possible to identify trends that may reveal the potential for new or widespread resistance. Routine surveillance of indicator bacteria helps to monitor the current efficacy of antibiotics. Surveillance plays a pivotal role in informing stewardship programs designed to combat the spread of antibiotic-resistant bacteria and the development of targeted infection control programs.[12,13] Leveraging some bacteria as sentinels can aid in understanding when and how resistance evolves and spreads, helping public health officials implement more effective strategies to preserve the effectiveness of existing antibiotics and protect public health.

In response to this global concern of antibiotic-resistant bacteria, 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.[14]

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 *Escherichia coli* Report provides summary data for USDA FSIS NARMS *Escherichia coli* isolates collected from 2014 through 2023 from food 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.[15,16]

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 by NARMS 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: adult 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 *E. coli* isolate testing are available in **Appendix A.** AST 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),[17] 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 *E. coli* 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 percentage of resistant isolate 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 panel used to test *E. coli* 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.

Escherichia coli

General Overview

E. coli is comprised of a diverse group of gram-negative bacteria that inhabit the intestinal tracts of people and animals.[18] While most *E. coli* strains are harmless and play an important role in intestinal health, certain strains can cause disease in both humans and animals. Harmful strains of *E. coli*, including Shiga toxin-producing *E. coli* (STEC) O157:H7, are primarily recognized for causing foodborne illnesses, while other strains are a significant cause of urinary tract infections, bloodstream infections, and other extraintestinal infections in both adult and newborn humans.[19] Strains of *E. coli* that cause foodborne illness are primarily transmitted to humans through the consumption of contaminated food or water, or through direct contact with infected animals or their environment. The infection can also be spread person-to-person.[20] Infections can cause problems ranging from mild diarrhea to severe complications like life-threatening hemolytic uremic syndrome (HUS), which can lead to kidney failure.[20] In the US, STEC infections lead to an estimated 357,000 illnesses, 3,150 hospitalizations, and 66 deaths annually.[21] Outbreaks have been linked to raw or undercooked ground beef, raw milk and cheeses, leafy greens, and other produce and foods contaminated with human feces or animal manure.[22]

Animals frequently carry strains of *E. coli* that are harmful to people. In fact, cattle are the primary reservoir for STEC O157:H7.[23] These harmful strains can be shed in animal manure and can contaminate meat during slaughter or carcass handling, as well as milk during the milking process. Environmental contamination with *E. coli* can also occur secondary to manure management practices.[20] The presence of harmful *E. coli* strains in meat and dairy products is suggestive of cross-contamination and can be used to monitor performance standards in food production.[24]

Most often, animals that harbor and shed *E. coli* bacteria do not display any clinical signs of illness and, instead, benefit from the bacteria's role in healthy digestion. However, some *E. coli* strains can cause disease in animals, including diarrhea in calves and piglets, as well as systemic infections in poultry.[25,26]

Most foodborne illnesses in people, especially those only causing mild diarrhea, are self-limiting and can be managed with supportive care alone. In these cases, treatment with antibiotics is unnecessary and also avoided as their use can prolong bacterial shedding and, in the case of STEC, increase the risk of HUS.[27,28] When antibiotics are indicated, as for extraintestinal infections, first-line choices include trimethoprim-sulfamethoxazole, nitrofurantoin, and fluoroquinolones.[18,28] Treatment for some multi-drug resistant strains of *E. coli*, including those with resistance due to extended-spectrum β-lactamase (ESBL), relies on carbapenems. Notably, *E. coli* is naturally resistant to macrolides, lincosamides, glycopeptides, linezolid, and, in some cases, penicillin.[29] As always, treatment decisions should be guided by AST results, clinical presentation, and local resistance patterns.

Many of the antibiotics used to treat *E. coli* infections in people 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**.

Non-harmful *E. coli* strains are recognized for their role in public health, particularly as indicators of fecal contamination, for monitoring food safety performance standards, and as sentinels for antimicrobial resistance.[24,30] Commensal *E. coli* strains are used as preferred indicator bacteria to assess water quality and to serve as a metric for signaling fecal pollution in recreational waters.[31] The detection of *E. coli* correlates with the presence of harmful gastrointestinal pathogens, which can pose significant health risks to populations that come into contact with contaminated water.[32] *E. coli* testing is performed in the food processing environment and at various stages in the food production cycle to evaluate process control and the effectiveness of sanitization procedures. The wide host range and ability to readily acquire resistance also make *E. coli* a reliable sentinel bacterium for tracking antibiotic resistance patterns,[18,30] including non-harmful *E. coli* isolated from environmental and food animal sources, such as at the time of slaughter. Monitoring the development of resistance in *E. coli* can guide public health and food safety policies, while also providing an early indicator of changes in resistance that may impact disease-causing bacteria.

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.[16] Cecal samples are obtained from individual cattle and swine, but are combined from five birds for chicken and turkey sampling procedures.[16]

The number of samples screened for *E. coli*, and screening results, for the NARMS Cecal Sample Program from food animals slaughtered in California is 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 978 *E. coli* isolates were obtained, and underwent AST, from screened NARMS cecal samples of the following animal species slaughtered in California between 2014 and 2023: 686 from adult cattle, 63 from chickens, 61 from turkeys, and 168 from swine.

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

Year		Cattle*	Chickens	Turkeys	Swine
2014	Null	231	12	7	40
	Negative	2	0	0	0
	Positive	33	1	6	9
2015	Null	174	16	10	22
	Negative	3	0	0	0
	Positive	44	2	5	12
2016	Null	154	9	4	31
	Negative	6	0	0	1
	Positive	95	4	11	31
2017	Null	181	10	10	27
	Negative	13	0	0	3
	Positive	109	6	3	35
2018	Null	202	14	11	32
	Negative	23	0	0	0
	Positive	136	14	7	36
2019	Null	238	13	5	25
	Negative	21	2	1	0
	Positive	96	14	9	15
2020	Null	194	5	1	15
	Negative	5	0	0	0
	Positive	30	3	3	7
2021	Null	233	7	2	7
	Negative	3	0	0	0
	Positive	25	1	1	2
2022	Null	277	15	7	34
	Negative	3	0	1	0
	Positive	33	6	4	9
2023	Null	220	15	6	19
	Negative	17	0	0	1
	Positive	50	5	7	2
Total		2851	174	121	415

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

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

Year	Cattle*	Chickens	Turkeys	Swine
2014	31	1	6	8
2015	43	2	5	12
2016	94	4	10	31
2017	107	6	3	34
2018	136	14	7	36
2019	96	15	9	16
2020	57	7	5	11
2021	39	3	5	9
2022	33	6	4	9
2023	50	5	7	2
Total	686	63	61	168

* 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 *E. coli* isolates from each animal species used for AST from California-slaughtered food animals, except cattle, is typically 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.[33] This means that, due to low numbers, the *E. coli* AST data for isolates from California-slaughtered food animals tested through NARMS each year may not be representative of the larger population of *E. coli* 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.[34] While the data showing the percentage of resistant isolates are presented for each animal species below, interpretations of population trends in *E. coli* susceptibility for isolates obtained from chicken, turkey, and, for most years, swine cannot be made due to the limited number of isolates tested for these host species.

E. coli Isolate Type

There are over 100 strains of *E. coli* that are grouped based on the inherent factors they possess and the type of disease they cause. More broadly, *E. coli* can be divided into commensal/harmless strains, harmful intestinal strains that cause diarrheal illness, and extraintestinal strains that cause disease outside the gastrointestinal tract. The sampling conducted by NARMS and reported here focuses on commensal, generic *E. coli* isolated from healthy animals at the time of slaughter and is, thus, used to monitor trends in antibiotic resistance. NARMS does not conduct serotyping within this context.

Trends in Resistance and Reduced Susceptibility to Antibiotics Using AST

Cattle

Figure 1 displays the percentage of *E. coli* isolates that underwent AST, from screened NARMS cecal samples collected from cattle slaughtered in California, and were categorized as resistant to the antibiotics included in the NARMS AST panel by year. For certain drugs, such as tetracycline, streptomycin, and sulfamethoxazole/sulfisoxazole, the percentage of resistant isolates varied from year to year but stayed below 35% across all years. In contrast, for all other antibiotics tested, the percentage of resistant isolates remained at or below 10% throughout the entire period.

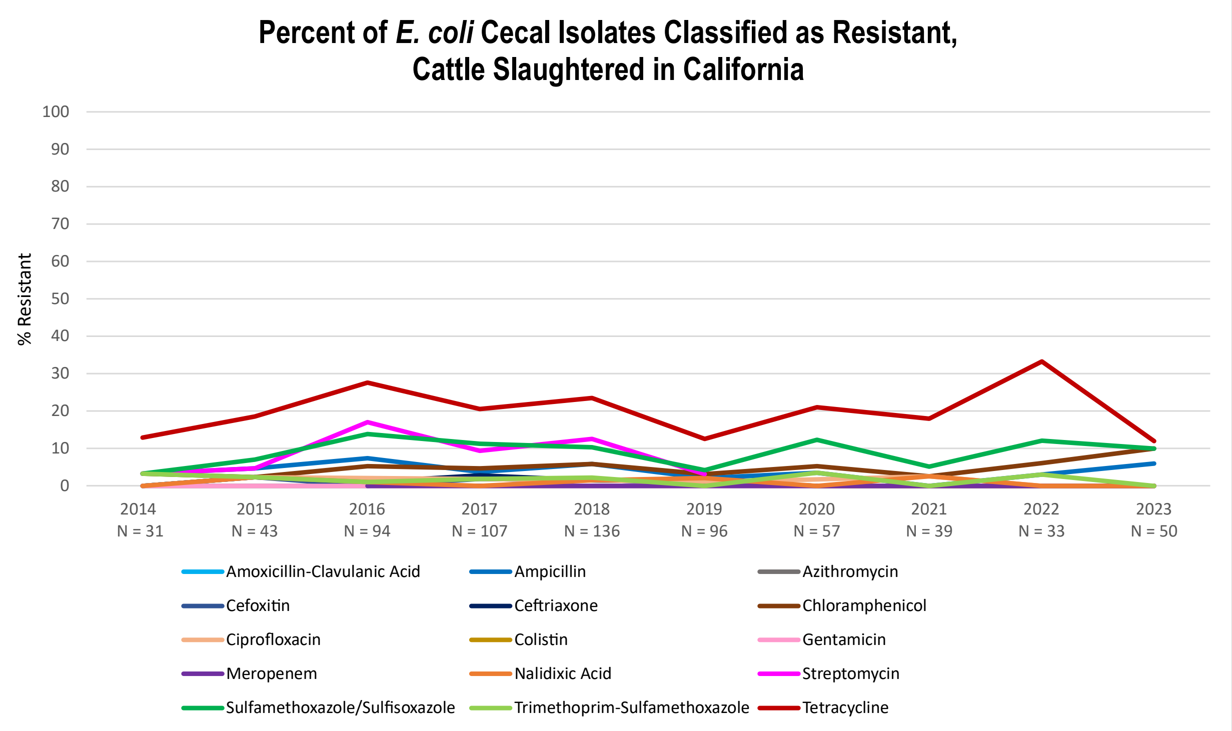


Figure 1. Data Trends in the Percent Resistant E. coli Isolates from Cattle Slaughtered in California, NARMS Cecal Isolates Tested with the NARMS Antibiotic Panel, 2014-2023.

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

The percentage of resistant isolates for screened NARMS cecal samples collected from cattle slaughtered in California that underwent AST for *E. coli* 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 *E. coli* in California-slaughtered cattle is the same as **Figure 1.**

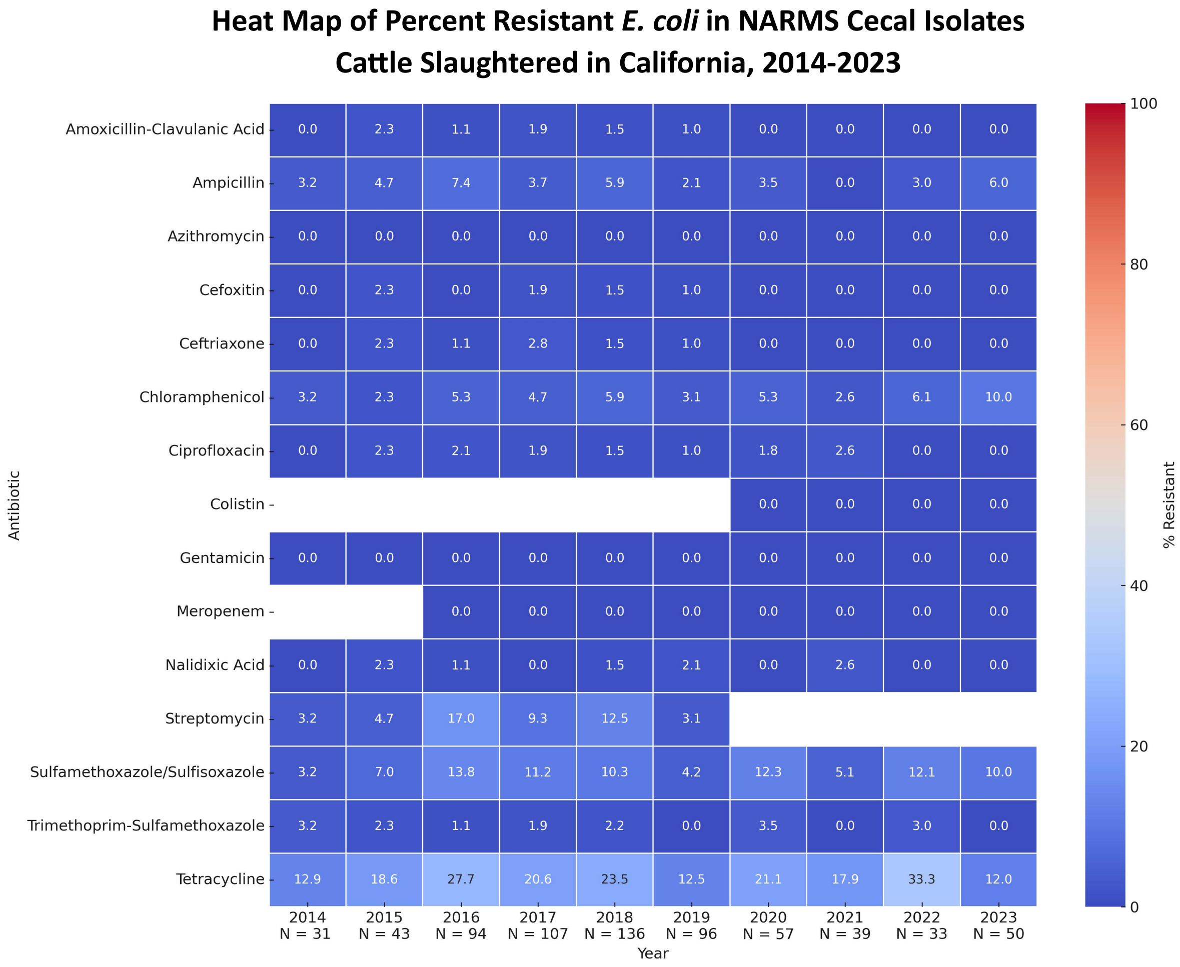


Figure 2. Heat Map Displaying Trends in the Percent Resistant E. coli Isolates from Cattle Slaughtered in California, NARMS Cecal Isolates Tested with the NARMS Antibiotic Panel, 2014-2023.
N indicates the number of isolates tested in a given year.

Chickens

The percentage of *E. coli* 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.

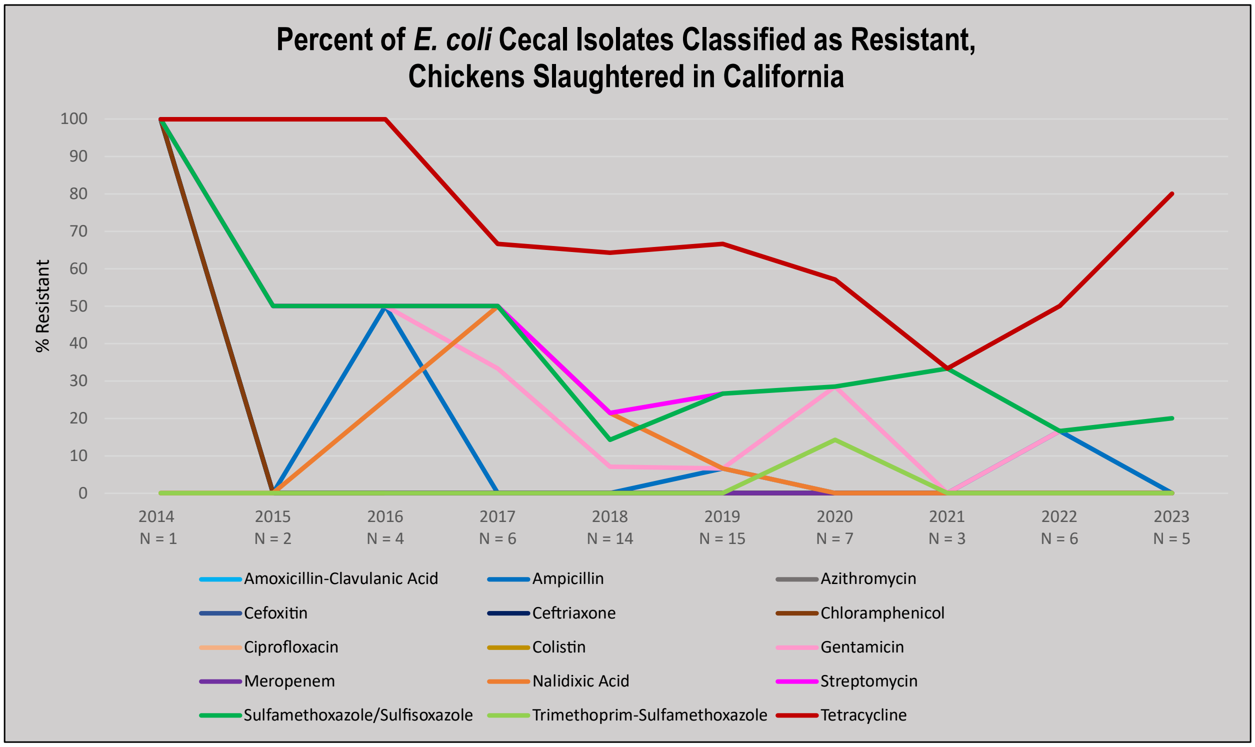
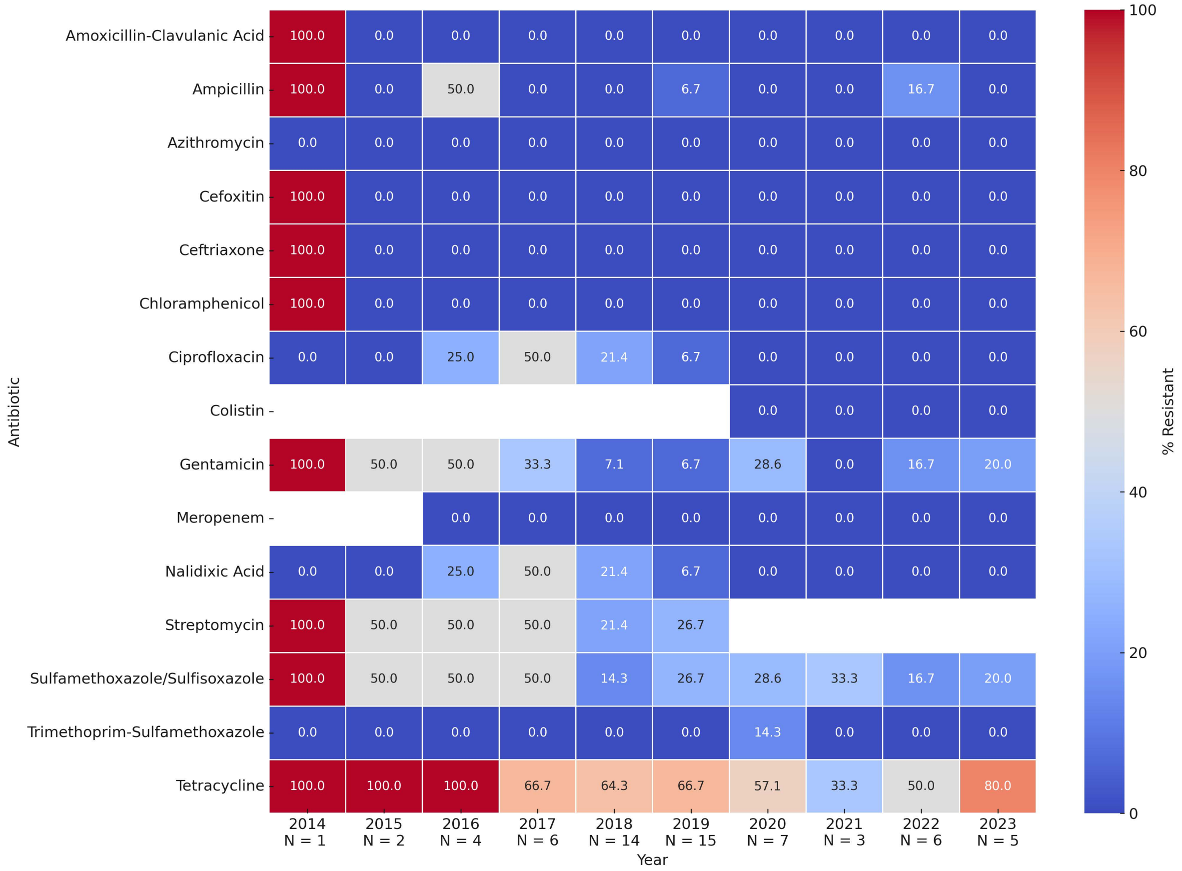


Figure 3. Trends in the Percent Resistant E. coli Isolates from Chickens Slaughtered in California, NARMS Cecal Isolates Tested with the NARMS Antibiotic Panel, 2014-2023.

N indicates the number of isolates tested in a given year. 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 *E. coli* in NARMS Cecal Isolates Chickens Slaughtered in California, 2014-2023



Antibiotic	2014 N = 1	2015 N = 2	2016 N = 4	2017 N = 6	2018 N = 14	2019 N = 15	2020 N = 7	2021 N = 3	2022 N = 6	2023 N = 5
Amoxicillin-Clavulanic Acid	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ampicillin	100.0	0.0	50.0	0.0	0.0	6.7	0.0	0.0	16.7	0.0
Azithromycin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cefoxitin	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ceftriaxone	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chloramphenicol	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ciprofloxacin	0.0	0.0	25.0	50.0	21.4	6.7	0.0	0.0	0.0	0.0
Colistin							0.0	0.0	0.0	0.0
Gentamicin	100.0	50.0	50.0	33.3	7.1	6.7	28.6	0.0	16.7	20.0
Meropenem			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nalidixic Acid	0.0	0.0	25.0	50.0	21.4	6.7	0.0	0.0	0.0	0.0
Streptomycin	100.0	50.0	50.0	50.0	21.4	26.7				
Sulfamethoxazole/Sulfisoxazole	100.0	50.0	50.0	50.0	14.3	26.7	28.6	33.3	16.7	20.0
Trimethoprim-Sulfamethoxazole	0.0	0.0	0.0	0.0	0.0	0.0	14.3	0.0	0.0	0.0
Tetracycline	100.0	100.0	100.0	66.7	64.3	66.7	57.1	33.3	50.0	80.0

Figure 4. Heat Map Displaying Trends in the Percent Resistant E. coli 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 *E. coli* 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.

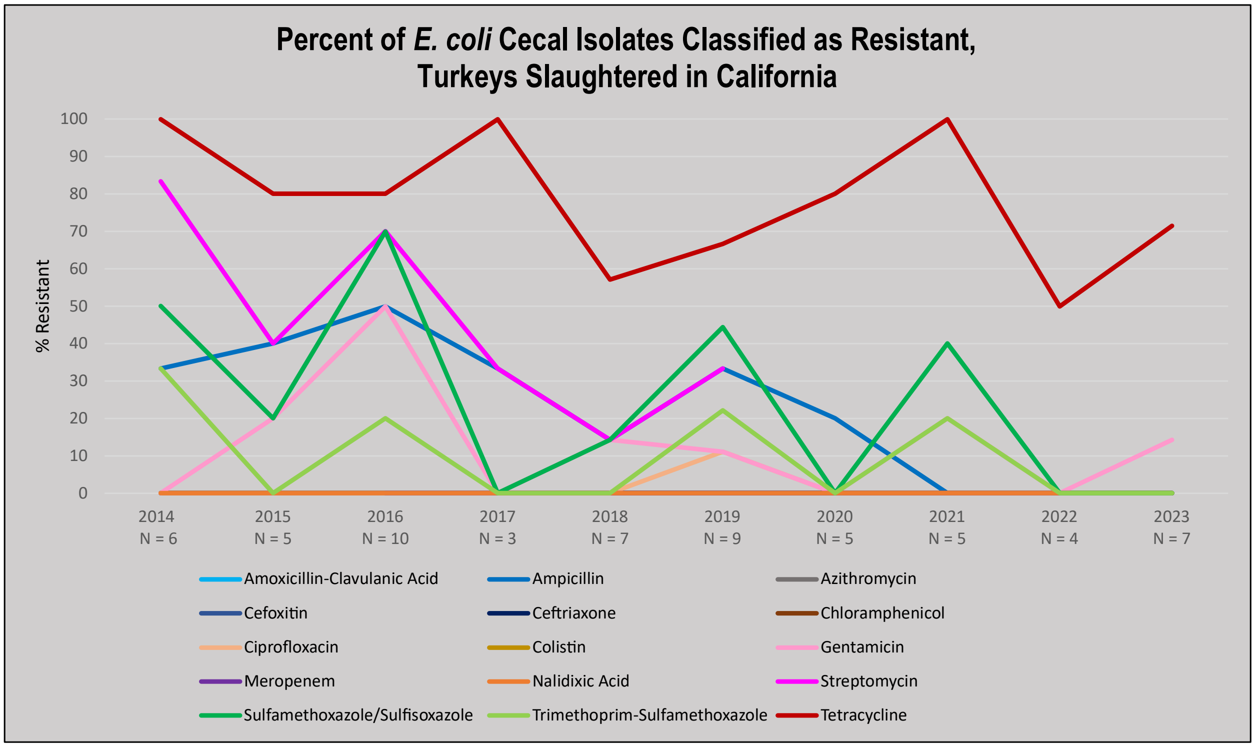


Figure 5. Trends in the Percent Resistant E. coli Isolates from Turkeys Slaughtered in California, NARMS Cecal Isolates Tested with the NARMS Antibiotic Panel, 2014-2023.

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 *E. coli* in NARMS Cecal Isolates, Turkeys Slaughtered in California, 2014-2023

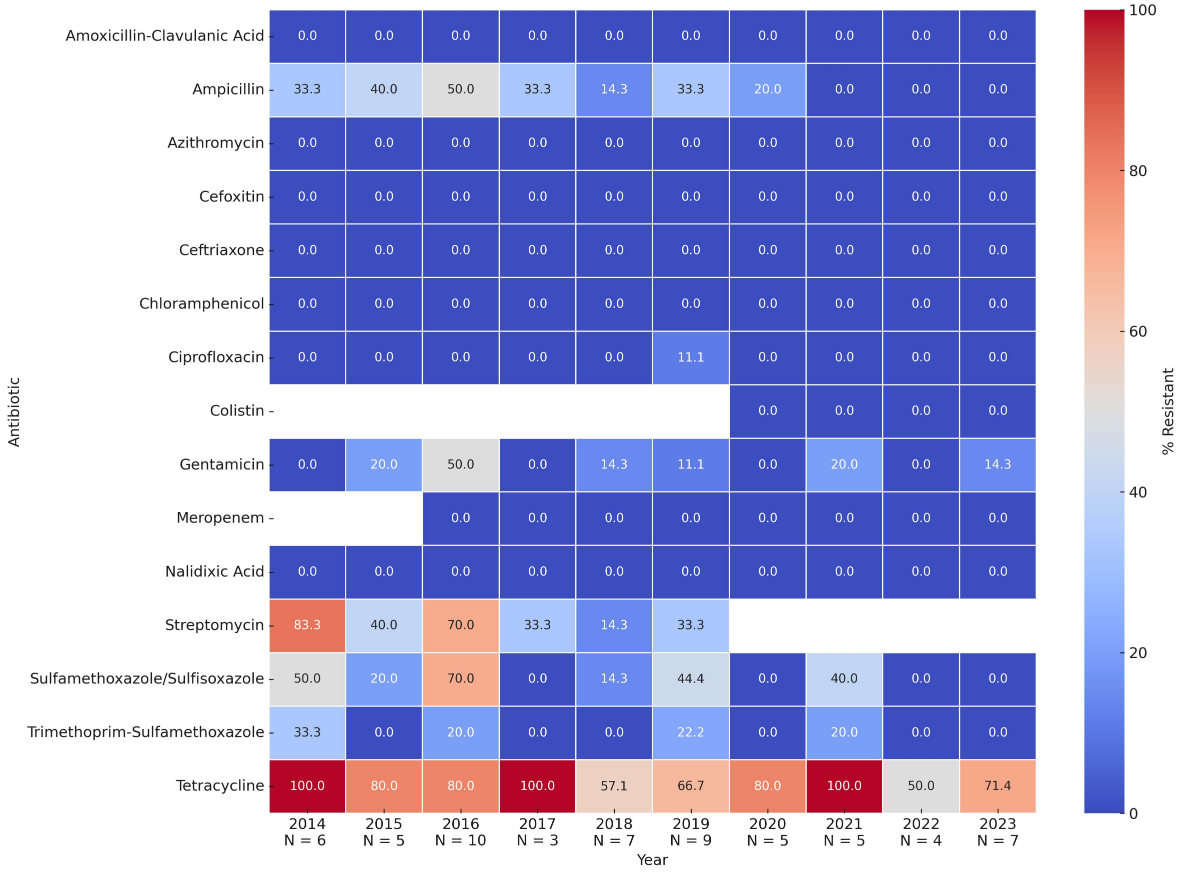


Figure 6. Heat Map Displaying Trends in the Percent Resistant E. coli Isolates in Turkeys Slaughtered in California, NARMS Cecal Isolates tested with the NARMS Antibiotic Panel, 2014-2023.
N indicates the number of isolates tested in a given year. Since less than 30 isolates were tested yearly, these 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 *E. coli* 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**. Since the number (N) of bacterial isolates that underwent AST for many of the years is below the CLSI-recommended threshold of 30 isolates, meaningful trends in susceptibility over time cannot be determined for this dataset. As such, an interpretation of the broader swine cecal data across California cannot be provided. Between 2016 and 2018, more than 30 isolates were tested, revealing fluctuations in the percentage of resistant isolates for many of the antibiotics tested during these three years.

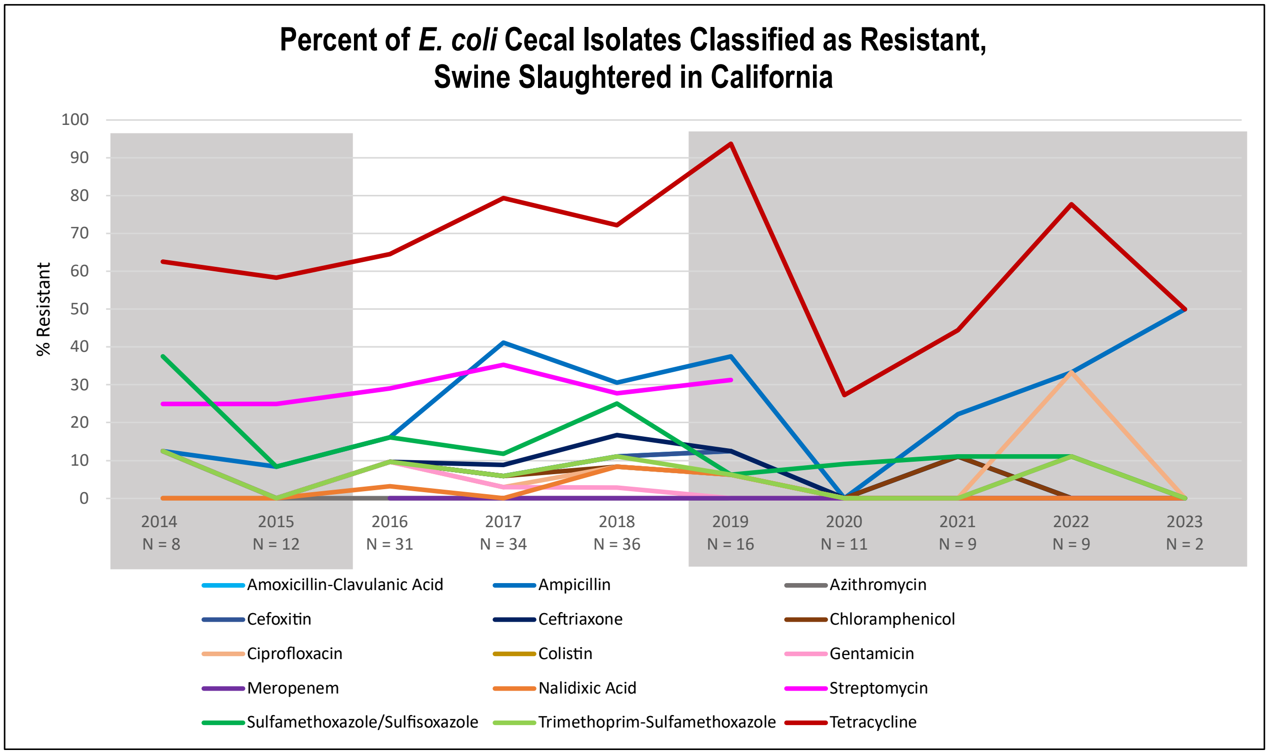
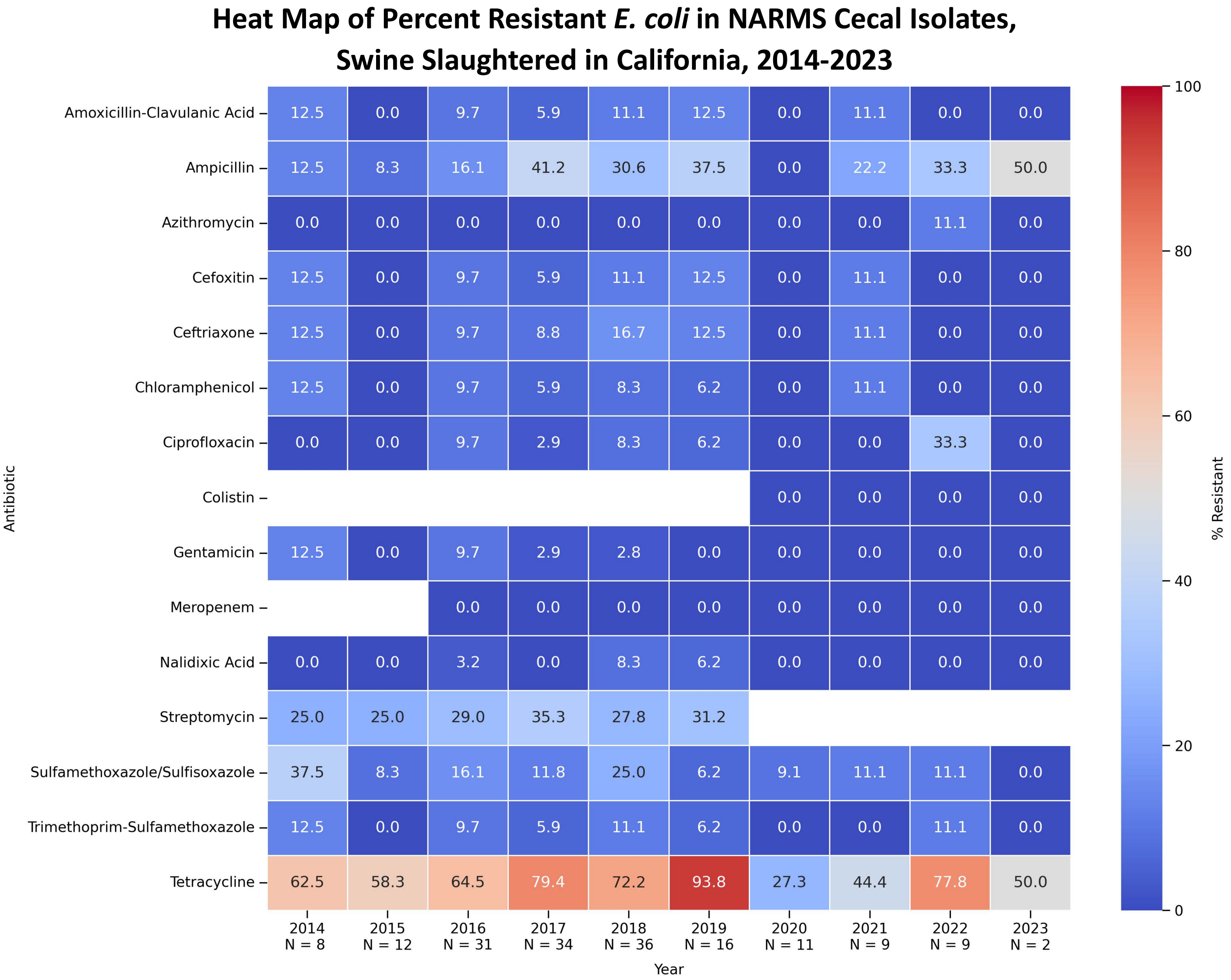


Figure 7. Trends in the Percent Resistant E. coli Isolates from Swine Slaughtered in California, NARMS Cecal Isolates Tested with the NARMS Antibiotic Panel, 2014-2023.

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 *E. coli* in NARMS Cecal Isolates, Swine Slaughtered in California, 2014-2023

Antibiotic	2014 N = 8	2015 N = 12	2016 N = 31	2017 N = 34	2018 N = 36	2019 N = 16	2020 N = 11	2021 N = 9	2022 N = 9	2023 N = 2
Amoxicillin-Clavulanic Acid	12.5	0.0	9.7	5.9	11.1	12.5	0.0	11.1	0.0	0.0
Ampicillin	12.5	8.3	16.1	41.2	30.6	37.5	0.0	22.2	33.3	50.0
Azithromycin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.1	0.0
Cefoxitin	12.5	0.0	9.7	5.9	11.1	12.5	0.0	11.1	0.0	0.0
Ceftriaxone	12.5	0.0	9.7	8.8	16.7	12.5	0.0	11.1	0.0	0.0
Chloramphenicol	12.5	0.0	9.7	5.9	8.3	6.2	0.0	11.1	0.0	0.0
Ciprofloxacin	0.0	0.0	9.7	2.9	8.3	6.2	0.0	0.0	33.3	0.0
Colistin							0.0	0.0	0.0	0.0
Gentamicin	12.5	0.0	9.7	2.9	2.8	0.0	0.0	0.0	0.0	0.0
Meropenem			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nalidixic Acid	0.0	0.0	3.2	0.0	8.3	6.2	0.0	0.0	0.0	0.0
Streptomycin	25.0	25.0	29.0	35.3	27.8	31.2				
Sulfamethoxazole/Sulfisoxazole	37.5	8.3	16.1	11.8	25.0	6.2	9.1	11.1	11.1	0.0
Trimethoprim-Sulfamethoxazole	12.5	0.0	9.7	5.9	11.1	6.2	0.0	0.0	11.1	0.0
Tetracycline	62.5	58.3	64.5	79.4	72.2	93.8	27.3	44.4	77.8	50.0

Figure 8. Heat Map Displaying Trends in the Percent Resistant E. coli 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, with the exception of 2016-2018, 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.[14] Below, trends in the percentage of resistant NARMS *E. coli* cecal isolates from cattle slaughtered in California are compared side-by-side with cattle data from 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 *E. coli* 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 isolates from California, which hinders meaningful interpretation.

Figure 9 shows that the percentage of antibiotic-resistant *E. coli* isolates from NARMS cecal samples collected from cattle slaughtered nationwide (excluding California) and in California has remained below 15% for most of the antibiotics tested over the five-year period. The only exception is tetracycline, where the proportion of resistant isolates consistently has been lower in cattle slaughtered in California, except that, in 2022, the percentage of resistant isolates in California was marginally higher than that observed in cattle from other participating states.

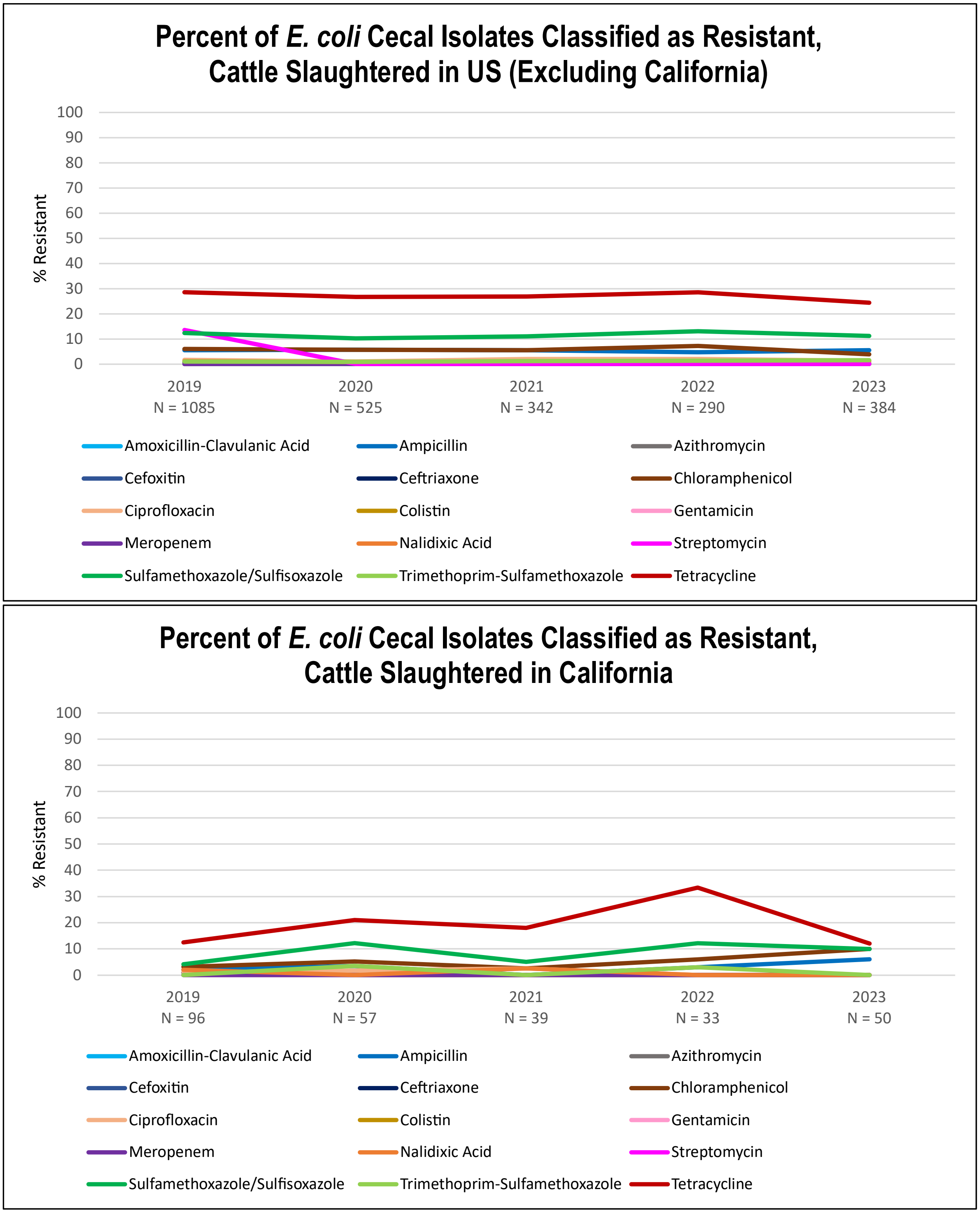
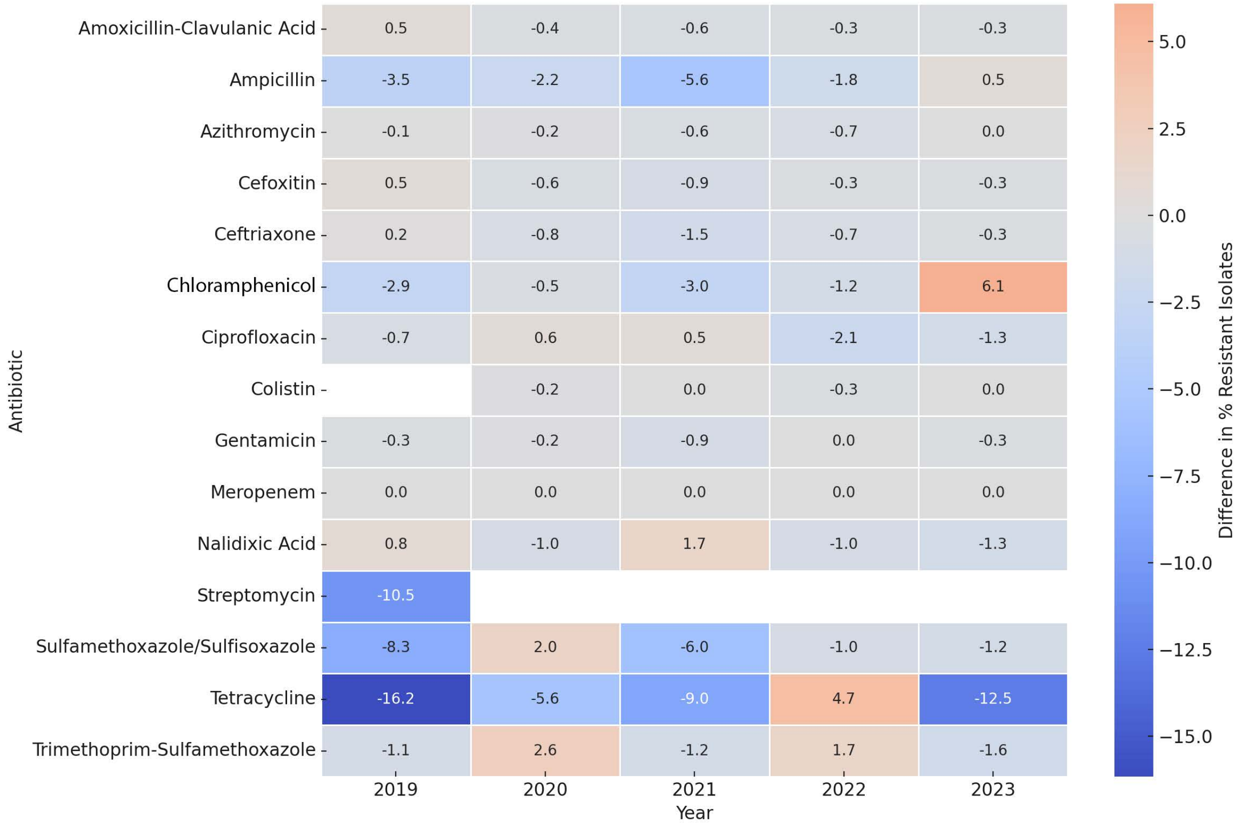


Figure 9. Comparison of Trends in the Percent Resistant E. coli Isolates from US NARMS Cattle Data (Excluding California) and Cattle Slaughtered in California Data, NARMS Cecal Isolates Tested with the NARMS Antibiotic Panel, 2019-2023.

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

Figure 10 is a heat map comparison of NARMS cecal *E. coli* isolates from cattle. This comparison graph illustrates the differences in the percentage of resistant NARMS *E. coli* isolates 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, while blue tones or negative differences reflect a lower percentage of resistant isolates in California-slaughtered cattle compared to other states participating in the NARMS program.

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



Antibiotic	2019	2020	2021	2022	2023
Amoxicillin-Clavulanic Acid	0.5	-0.4	-0.6	-0.3	-0.3
Ampicillin	-3.5	-2.2	-5.6	-1.8	0.5
Azithromycin	-0.1	-0.2	-0.6	-0.7	0.0
Cefoxitin	0.5	-0.6	-0.9	-0.3	-0.3
Ceftriaxone	0.2	-0.8	-1.5	-0.7	-0.3
Chloramphenicol	-2.9	-0.5	-3.0	-1.2	6.1
Ciprofloxacin	-0.7	0.6	0.5	-2.1	-1.3
Colistin		-0.2	0.0	-0.3	0.0
Gentamicin	-0.3	-0.2	-0.9	0.0	-0.3
Meropenem	0.0	0.0	0.0	0.0	0.0
Nalidixic Acid	0.8	-1.0	1.7	-1.0	-1.3
Streptomycin	-10.5				
Sulfamethoxazole/Sulfisoxazole	-8.3	2.0	-6.0	-1.0	-1.2
Tetracycline	-16.2	-5.6	-9.0	4.7	-12.5
Trimethoprim-Sulfamethoxazole	-1.1	2.6	-1.2	1.7	-1.6

Figure 10. Heat Map of the Difference of the Percent Resistant E. coli 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 *E. coli* 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.

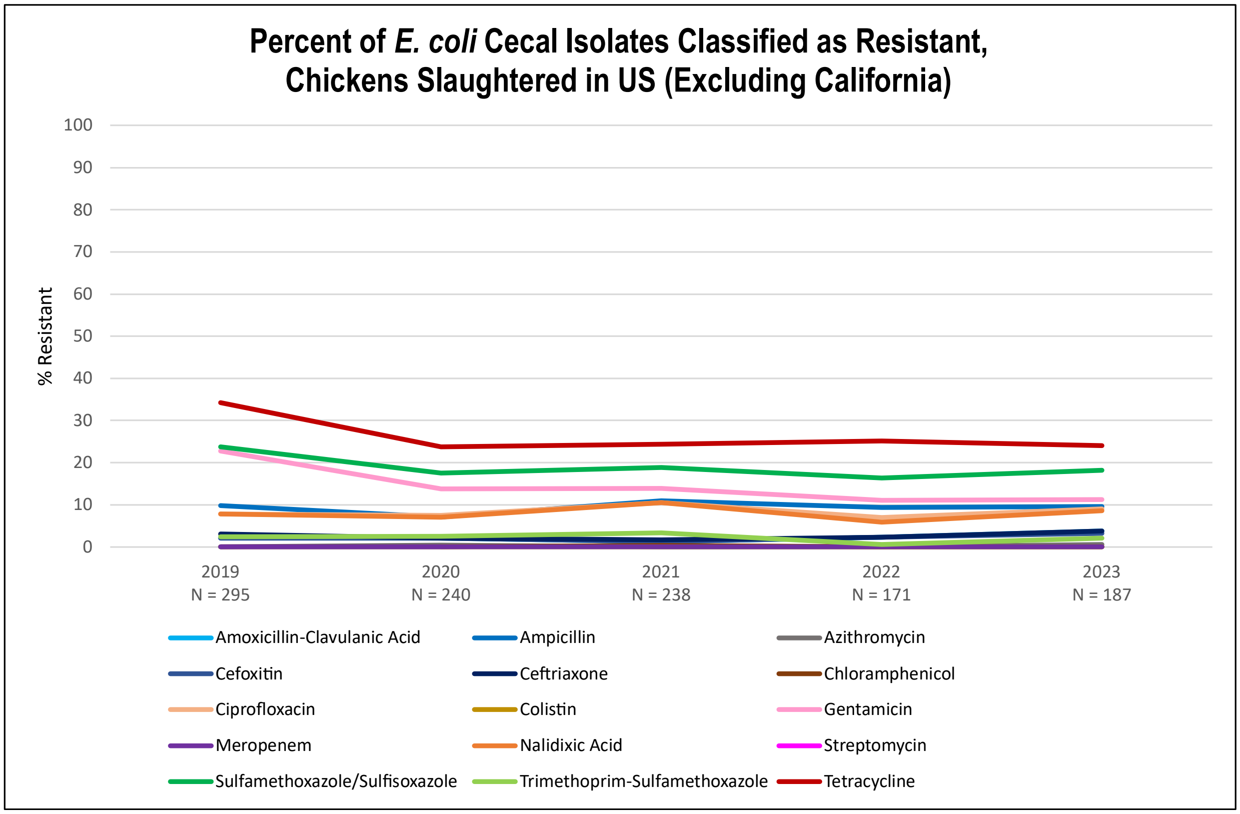


Figure 11. The Percent Resistant E. coli Isolates in Chickens, US NARMS Data (Excluding California), Cecal Isolates, 2019-2023.

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

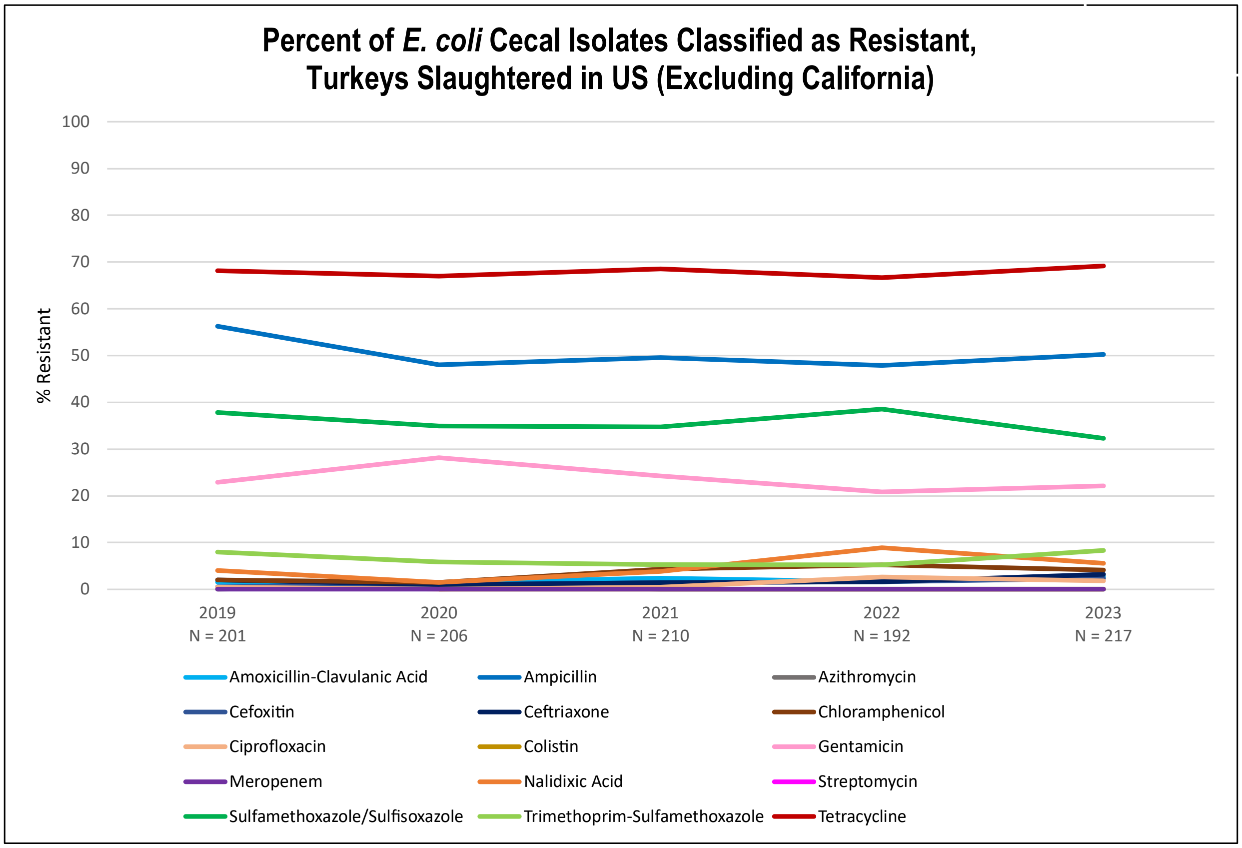


Figure 12. The Percent Resistant E. coli Isolates in Turkeys, US NARMS Data (Excluding California), Cecal Isolates, 2019-2023.

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

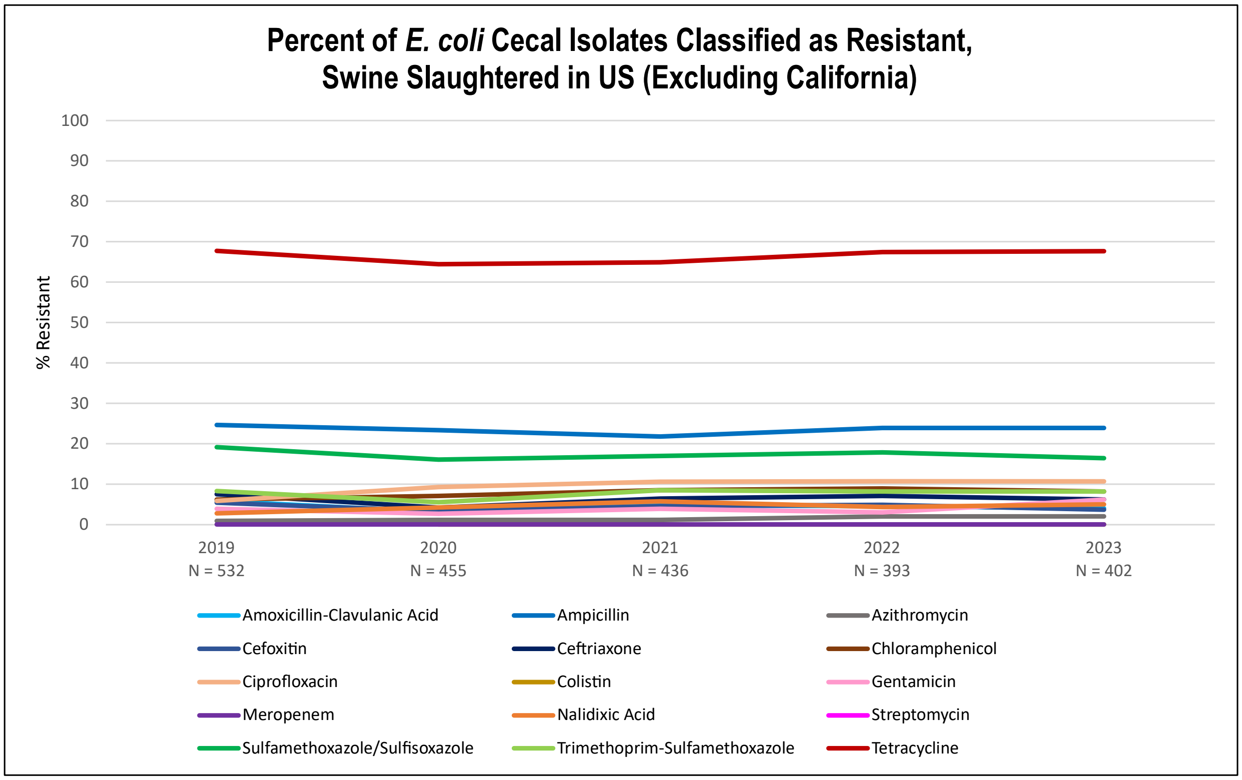


Figure 13. The Percent Resistant E. coli Isolates in Swine, US NARMS Data (Excluding California), Cecal Isolates, 2019-2023.

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.[35] 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 *E. coli* Isolates, 1996-2024.[36]

	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 *E. coli* isolates from chickens and retail meats began in 2000 and 2002, respectively. Testing of *E. coli O157* isolates from humans began in 1996 and a study of *E. coli* isolates from people in the community began in 2004.

[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 *E. coli*.[36]

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 µg/ml) as a marker for emerging fluoroquinolone resistance (CLSI, 2017).

Appendix C

Table C1. NARMS *E. coli* 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), IMM (cattle)
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, turkeys), IM (cattle, swine), PO (cattle), TOP (cattle, swine)

* Antibiotics above are those included in the NARMS antibiotic panel for *E. coli* AST.

[†] Food animal approved use of these specific drugs and closely related drug formulations approved per the Code of Federal Regulations, and as of publication, for use in food animals are listed.

Feed: medicated feed
Water: medicated water
PO: oral bolus
IM: intramuscular
IMM: intramammary
IV: intravenous
SC: subcutaneous
SCi: subcutaneous implant
TOP: topical
AU: otic
OU: ocular

References

1. Feng Q, Frana T, Logue CM, et al. Comparison of Antimicrobial Resistance Profiles in Salmonella spp. from Swine Upon Arrival and Postslaughter at the Abattoir. *Microb Drug Resist* 2021;27:1144-1154.

2. Koutsoumanis K, Allende A, Álvarez-Ordóñez A, et al. Transmission of antimicrobial resistance (AMR) during animal transport. *Efsa j* 2022;20:e07586.

3. Gaire TN, Odland C, Zhang B, et al. Slaughtering processes impact microbial communities and antimicrobial resistance genes of pig carcasses. *Science of The Total Environment* 2024;946:174394.

4. CDC. Antibiotic resistance threats in the United States, 2019. Atlanta, Georgia: U.S. Department of Health and Human Services, CDC, 2019.

5. Samtiya M, Matthews KR, Dhewa T, et al. Antimicrobial Resistance in the Food Chain: Trends, Mechanisms, Pathways, and Possible Regulation Strategies. *Foods* 2022;11.

6. CDC. Surveillance for Foodborne Disease Outbreaks United States, 2017: Annual Report. Atlanta Georgia: U.S. Department of Health and Human Services, CDC, 2019.

7. CDC. Surveillance for Foodborne Disease Outbreaks United States, 2016: Annual Report. Atlanta Georgia: U.S. Department of Health and Human Services, CDC, 2018.

8. Byappanahalli Muruleedhara N, Nevers Meredith B, Korajkic A, et al. Enterococci in the Environment. *Microbiology and Molecular Biology Reviews* 2012;76:685-706.

9. Ibekwe AM, Obayiuwana AC, Murinda SE. Enterococcus Species and Their Antimicrobial Resistance in an Urban Watershed Affected by Different Anthropogenic Sources. *Water*, 2024.

10. Ramos S, Silva V, Dapkevicius MLE, et al. Enterococci, from Harmless Bacteria to a Pathogen. *Microorganisms* 2020;8.

11. Zaidi S-e-Z, Zaheer R, Zovoilis A, et al. Enterococci as a One Health indicator of antimicrobial resistance. *Canadian Journal of Microbiology* 2024;70:303-335.

12. WHO. Integrated surveillance of antimicrobial resistance in foodborne bacteria: application of a one health approach: guidance from the WHO Advisory Group on Integrated Surveillanec of Antimicrobial Resistance (AGISAR). Geneva, 2017.

13. Boccella M, Santella B, Pagliano P, et al. Prevalence and Antimicrobial Resistance of Enterococcus Species: A Retrospective Cohort Study in Italy. *Antibiotics (Basel)* 2021;10.

14. FDA. NARMS Now. Rockville, MD: U.S. Department of Health and Human Services.

15. FDA. The National Antimicrobial Resistance Monitoring System Manual of Laboratory Methods. 4th ed, 2020.

16. FDA. NARMS Methodology. *NARMS Supplemental Material*, 2023.

17. FDA. Interpretive Criteria for Susceptibility Testing. *NARMS Supplemental Material*, 2023.

18. Tadesse DA, Zhao S, Tong E, et al. Antimicrobial drug resistance in Escherichia coli from humans and food animals, United States, 1950-2002. *Emerg Infect Dis* 2012;18:741-749.

19. Poolman JT, Wacker M. Extraintestinal Pathogenic Escherichia coli, a Common Human Pathogen: Challenges for Vaccine Development and Progress in the Field. *J Infect Dis* 2016;213:6-13.

20. Hussein HS, Bollinger LM. Prevalence of Shiga toxin-producing Escherichia coli in beef cattle. *J Food Prot* 2005;68:2224-2241.

21. Scallan Walter EJ, Cui Z, Tierney R, et al. Foodborne Illness Acquired in the United States-Major Pathogens, 2019. *Emerg Infect Dis* 2025;31:669-677.

22. FDA. Escherichia coli (E. coli): FDA, 2019.

23. Gyles CL. Shiga toxin-producing Escherichia coli: an overview. *J Anim Sci* 2007;85:E45-62.

24. USDA. Industry Guideline for Minimizing the Risk of Shiga Toxin-Producing Escherichia coli (STEC) in Beef (including Veal Slaughter Operations 2021 Guideline, 2021.

25. Nagy B, Fekete PZ. Enterotoxigenic Escherichia coli in veterinary medicine. *International Journal of Medical Microbiology* 2005;295:443-454.

26. Dho-Moulin M, Fairbrother JM. Avian pathogenic Escherichia coli (APEC). *Vet Res* 1999;30:299-316.

27. Sevilla P, Martínez A, Nuevo DV, et al. Impact of antibiotic treatment on hemolytic uremic syndrome risk in Escherichia coli O157 infections: a comprehensive systematic review and meta-analysis. *European Journal of Clinical Microbiology & Infectious Diseases* 2025;44:1763-1778.

28. CDC. E. coli Infection (Escherichia coli) Information for Clinicians, 2024.

29. Galgano M, Pellegrini F, Catalano E, et al. Acquired Bacterial Resistance to Antibiotics and Resistance Genes: From Past to Future. *Antibiotics (Basel)* 2025;14.

30. Anjum MF, Schmitt H, Börjesson S, et al. The potential of using E. coli as an indicator for the surveillance of antimicrobial resistance (AMR) in the environment. *Current Opinion in Microbiology* 2021;64:152-158.

31. Odonkor ST, Ampofo JK. Escherichia coli as An Indicator of Bacteriological Quality of Water: An Overview. *Microbiology Research* 2013;4:e2.

32. Pandey PK, Kass PH, Soupir ML, et al. Contamination of water resources by pathogenic bacteria. *AMB Express* 2014;4:51.

33. CLSI. Analysis and Presentation of Cumulative Antimicrobial Susceptibility Test Data. 5th ed. CLSI guideline M39: Clinical and Laboratory Standards Institute, 2022.

34. Tran C, Hargy J, Hess B, et al. Estimated Impact of Low Isolate Numbers on the Reliability of Cumulative Antibiogram Data. *Microbiol Spectr* 2023;11:e0393922.

35. USDA. Food Safety and Inspection Service Annual Sampling Plan Fiscal Year 2025., 2025.

36. USDA. California Specific FSIS NARMS data from 1/1/2013 through 12/31/2023. Obtained through FOIA request no. 2024-FSIS-00198, recived June 2024. Unpublished data.