USDA APHIS VS National Animal Health Laboratory Network (NAHLN) Antimicrobial Resistance Pilot Project

Year 1 report: 2018

Table of Contents

Executive Summary

The primary focus of this project is to develop a sampling stream to monitor antimicrobial resistance (AMR) profiles in animal pathogens routinely isolated by veterinary clinics and diagnostic laboratories across the U.S. This project was developed as a collaboration between veterinary diagnostic laboratories belonging to the American Association of Veterinary Laboratory Diagnosticians (AAVLD), the Clinical Laboratory Standards Institute (CLSI), Food and Drug Administration Center for Veterinary Medicine's Veterinary Laboratory Investigation and Response Network (Vet-LIRN), U.S. Department of Agriculture Animal and Plant Health Inspection Service (APHIS) Veterinary Services Centers for Epidemiology and Animal Health (CEAH) and USDA APHIS, National Animal Health Laboratory Network (NAHLN).

This report describes information collected through the NAHLN pilot project, and funded through USDA. Year 1 of this pilot covers the time period from January 1, 2018 through December 19, 2018. Nineteen laboratories (18 with membership in the NAHLN and one laboratory outside the NAHLN, associated with a U.S. college of veterinary medicine) contributed antimicrobial susceptibility testing data from 3213 veterinary bacterial isolates. Four major livestock species (cattle, swine, poultry and horses), and two companion animal species (dogs and cats) were covered. Bacterial isolates surveyed were *Escherichia coli (E. coli)* (1700 isolates across all animal species)*, Salmonella enterica* spp. (584 isolates across all species), *Mannheimia haemolytica* (380 isolates from cattle), and *Staphylococcus intermedius* group (548 isolates from dogs and cats).

Evaluation of antibiotic resistance was confounded by the fact that veterinary clinical breakpoints have not been established for the majority of antibiotic/bacterial combinations in most animal species. Notable exceptions were for dogs/*E. coli*, dogs/*Staphylococcus* spp. and cattle/*M. haemolytica*. Overall, variable resistance rates were noted for those antibiotics with clinical breakpoints. Of note was amoxicillin/clavulanic acid, which had resistance rates of 100% for *E. coli* recovered from non-urinary tract infections in dogs and cats, and ampicillin, with 100% resistance for *E. coli* recovered from feline urinary tract infections. For livestock species, resistance rates across drugs with clinical breakpoints ranged from 0-31%. However, this may be conservative due to the lack of clinical breakpoints in most animal species.

Multi-drug resistance (MDR), defined as acquired non-susceptibility to at least one agent in three or more antimicrobial classes, was evaluated in all animal species where sufficient clinical breakpoints were available. Almost 75% of canine *E. coli* isolates associated with non-urinary tract infections were multi-drug resistant, as were 56.9% of oxacillin-resistant canine Staphylococcus non-urinary tract infections. Conversely, MDR was substantially lower in other animal species/pathogens; 18.7% for cattle *M. haemolytica* isolates, 6.3% for equine *E. coli* isolates, 4.8% for canine UTI isolates, and 2.9% for feline *E. coli* non-urinary tract infection isolates. Again, antibiotic resistance reported here may be conservative due to the lack of clinical breakpoints for most antibiotic classes in most animal species.

Epidemiological cutoff values (ECVs) were also briefly evaluated in this report. ECVs distinguish between organisms with and without phenotypically expressed resistance mechanisms for a bacterial species and a corresponding antibiotic. Generally, these two groups are termed "non-wild type" and "wild type" respectively. ECVs are not designed to be used to guide therapy, but instead serve as a standardized method for comparison of antibiotic resistance internationally, as each country may set clinical breakpoints differently.

Introduction

Antimicrobial resistance is considered one of the most serious global health threats to both animals and humans at this time. The One Health concept recognizes that the health of humans and animals is irrevocably linked and closely connected to the environment. Antimicrobial resistance (AMR) is a multi-faceted issue that requires a One Health approach, as everyone has a shared responsibility in limiting its impact.

In 2015, the President of the United States released a National Action Plan for Combatting Antibiotic Resistant Bacteria (CARB). This National Action Plan calls for collaborative action by the U.S. Government to strengthen our resources to address this issue. The USDA has taken steps to respond to this need by developing a concurrent Action Plan, aligned with the CARB Plan, which identifies goals and objectives for addressing antibiotic resistance and judicious use of antimicrobial agents in agriculture. Subsequently, APHIS-Veterinary Services (APHIS-VS) outlined a series of longitudinal, cross-sectional, and targeted studies designed to provide information on the initiatives found in USDA's plan. This document can be found on the Center for Epidemiology and Animal Health's (CEAH's) web site at https://www.aphis.usda.gov/animal_health/nahms/amr/downloads/ProposedInitiatives.pdf. The proposed VS initiatives identifies multiple studies to be performed through the VS National Animal Health Monitoring System (NAHMS), including the project described here.

In FY 2015 the NAHLN engaged AAVLD to initiate a joint working group comprised of representatives from AAVLD veterinary diagnostic laboratories, the Clinical and Laboratory Standards Institute (CLSI), Food and Drug Administration Center for Veterinary Medicine's Veterinary Laboratory Investigation and Response Network (FDA-CVM VetLIRN), USDA-APHIS Veterinary Services Centers for Epidemiology and Animal Health (CEAH) and USDA APHIS, National Animal Health Laboratory Network (NAHLN). The working group developed recommendations for a standardized antimicrobial susceptibility testing and data collection plan to leverage data from veterinary diagnostic laboratories in the U.S. This data will help inform USDA and FDA on the status of antimicrobial resistance in pathogens of importance to the veterinary community.

The primary goal of this project is to monitor AMR profiles in animal pathogens routinely isolated by veterinary clinics and diagnostic laboratories across the U.S. By developing a centralized data collection and reporting process across all of these laboratories, data can be monitored for trends in antimicrobial resistance phenotypes and genotypes to identify new or emerging resistance profiles, to help monitor the continued usefulness of antibiotics over time, and to provide information back to our stakeholders regarding these trends.

Materials & Methods

Laboratory Enrollment

A request for participation was distributed through the American Association of Veterinary Laboratory Diagnosticians (AAVLD). Participation was open to both public and private veterinary diagnostic laboratories and clinics in the U.S. Laboratory applications were reviewed, with factors such as

geographic and animal population representativeness taken into account to maximize representation of isolates surveyed at a national level. For the initial year of the pilot, 19 laboratories were enrolled from the following states: Alabama, California, Colorado, Florida, Georgia, Indiana, Kentucky, Michigan, Minnesota, Missouri, Mississippi, Nebraska, New York, Ohio, Pennsylvania, South Dakota, Texas, Washington and Wisconsin. Eighteen of these laboratories were State or University-associated veterinary diagnostic laboratories who had membership in the NAHLN, and one laboratory was outside of the NAHLN but is associated with a U.S. college of veterinary medicine.

Pathogen Selection

Based on the joint APHIS-AAVLD working group recommendations, four veterinary pathogens were identified for monitoring during the initial year of the pilot project; *Escherichia coli*, *Salmonella* enterica spp., *Mannheimia haemolytica* and *Staphylococcus intermedius* group. This list was derived through objective analysis of several criteria, including the impact of the disease on each animal commodity/industry, its impact to public health, if antibiotics used to treat the disease were also on the WHO and OIE lists of antimicrobials of critical importance to human and veterinary medicine, the technical difficulty of performing antimicrobial susceptibility testing (AST) on the bacterial pathogen, and whether antibiotics of interest were available on commercial microdilution plates and in appropriate ranges.

For each pathogen, a list of recommended animal species was developed for surveillance tracking (Table 1).

Table 1. Recommended pathogen/animal species for surveillance.

Bacterial pathogen	Animal Species
Escherichia coli	cattle, swine, poultry, horses, dogs, cats
Salmonella enterica	cattle, swine, poultry, horses, dogs, cats
Mannheimia haemolytica	cattle
Staphylococcus intermedius group*	dogs, cats

*Includes *S. intermedius, S. pseudintermedius* and *S. delphini*.

Isolates were selected by participating laboratories for inclusion in the pilot project based on the criteria that isolates must be; i) identified to the genus and species level (and serotype level for Salmonella) using commonly accepted veterinary microbiology laboratory techniques, ii) associated with clinical disease or diagnostic findings, and iii) from unique animal sources (no more than one isolate from the same herd/flock, farm/household or owner).

Epidemiological data reported:

In order to preserve and protect personally identifiable information associated with isolates, an identification numbering scheme was developed. Participating laboratories assigned a unique identifier (ID) to each isolate based on this scheme, and all data reported to APHIS were submitted only under this unique ID. The following epidemiological data was collected for each isolate, along with the minimum inhibitory concentration (MIC) values of all antibiotics tested, regardless of applicability for clinical or therapeutic use:

- purpose of submission (for example, general diagnostic)
- bacterial organism (genus/species/serotype)
- date of isolation
- animal species

- state of origin of animal
- specimen/source tissue isolate was recovered from (for example, oropharyngeal swab, lung tissue, or feces)
- final diagnosis or results for case

Antimicrobial Susceptibility Testing and Reporting.

Susceptibility Testing

Antimicrobial susceptibility testing (AST) was conducted using the Sensititre™ (Thermo Fisher Scientific, Waltham, MA) broth microdilution platform. Commercially available Sensititre™ microdilution plates were used for testing the selected organisms. The appropriate plate to test each animal species was used according to Table 2.

Table 2. Sensititre™ plates used for Year 1 of the pilot project.

Animal species	Bacterial Pathogen			
	E. coli	*Salmonella spp.*	*M. haemolytica*	*S. intermedius grp.*
Cattle	BOPO6F or 7F	BOPO6F or 7F	BOPO6F or 7F	N/A*
Swine	BOPO6F or 7F	BOPO6F or 7F	N/A	N/A
Poultry	Avian1F	Avian1F	N/A	N/A
Horses	Equin1F	Equin1F	N/A	N/A
Cats	COMPGN1F	COMPGN1F	N/A	Companion GP1F
Dogs	COMPGN1F	COMPGN1F	N/A	Companion GP1F

**N/A = not applicable.*

Susceptibility Test Interpretation and Reporting

For this study, both the BOPO 6F and BOPO 7F plates were used. Differences between the two plates are provided in Table 3.

Table 3. Comparison of antibiotics and antibiotic dilutions between the Sensititre™ BOPO6F and BOPO7F veterinary antibiotic sensitivity plates.

ANTIBIOTIC	Antibiotic Concentrations (µg/mL)*	
	BOPO6F	BOPO7F
Ampicillin	0.25-16	0.25-16
Ceftiofur	0.25-8	1-8
Chlortetracycline	0.5-8	absent
Clindamycin	0.25-16	0.25-16
Danofloxacin	0.12-1	0.12-1
Enrofloxacin	0.12-2	0.12-2
Florfenicol	0.25-8	0.25-8
Gamithromycin	absent	1-8
Gentamicin	1-16	1-16
Neomycin	4-32	4-32
Oxytetracycline	1-8	absent
Penicillin	0.12-8	0.12-8
Spectinomycin	8-64	8-64
Sulphadimethoxine	256	256
Tetracycline	absent	0.5-8
Tiamulin	1-32	0.5-32
Tildipirosin	absent	1-16

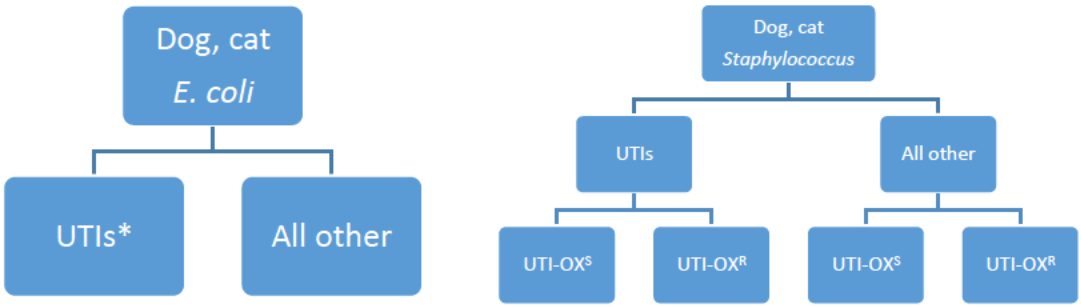
Tilmicosin	4-64	2-16
Trimethoprim/sulfamethoxazole	2/38	2/38
Tulathromycin	1-64	8-64
Tylosin	0.5-32	0.5-32

Cells shaded in orange indicate differences in antibiotics between the two plates. Cells shaded in blue indicate different concentrations of the same antibiotic.

* Concentrations are present on the plate as a series of two-fold dilutions

Companion animal *E. coli* and *Staphylococcus intermedius* group isolates were further differentiated into two groups; those isolates cultured from urine as urinary tract infections (UTIs) and all other isolates (Figure 1). This was done to improve interpretation of AST results, as several antibiotics have differing breakpoints for urinary tract infections compared with skin, soft tissue infections, or infections in other body sites. Methicillin-resistant *Staphylococcus* is also an increasing concern for veterinary medicine. Thus, an attempt was made to identify those isolates that may be candidates for further screening, based on resistance to oxacillin. One confounding factor is that veterinary-specific breakpoints have not been established for oxacillin in isolates from dogs or cats, so human-derived breakpoints were used to categorize these isolates.

Figure 1. Breakdown of companion animal isolates for AST.



*UTIs = isolates recovered from urinary tract infections; OX^S = oxacillin sensitive; OX^R = oxacillin resistant.

** Oxacillin sensitivity/resistance based on human breakpoints

Results

Minimum inhibitory concentration data, *Salmonella* serotypes, and clinical symptoms/diagnoses are provided for all animal species in Appendices A-F. Isolates were recovered from routine diagnostic cases submitted to participating laboratories between January and December, 2018. Data are provided for all antibiotics represented on the commercial plates used for this pilot, regardless of therapeutic use. Susceptible, intermediate and resistant interpretations are provided only for those antibiotics that have both pathogen-specific and species-specific clinical breakpoints established, as reported in the Clinical Laboratory Standards Institute's 2018 veterinary standard Vet 08 (CLSI, 2018).

Cattle - General

Information regarding production type (dairy, beef), age, or production type/class was not collected. Aggregate data are provided for all antibiotics found on both the BOPO6F and BOPO7F plates; thus the number of isolates surveyed for some antibiotics may differ.

Cattle - *E. coli*

Only two antibiotics have clinical breakpoints for *E. coli* in cattle; ampicillin and ceftiofur. Ampicillin only has breakpoints established for metritis, while ceftiofur only has breakpoints established for mastitis. In this dataset of 372 isolates, only three isolates were associated with a diagnosis of metritis: one susceptible to ampicillin, and two resistant. Similarly, only five isolates were recovered from mastitis cases; all were susceptible to ceftiofur. All MIC data for bovine *E. coli* isolates are in Table 4, Appendix A.

Overall, the most common clinical symptom or diagnosis associated with *E. coli* infections in cattle was diarrhea/enteric infections (217/372, 58.3%), followed by septicemia (40/372, 10.8%) and pneumonia (36/372, 9.7%). Additional diagnoses/clinical symptoms and percentage of isolates associated with them can be found in Table 5, Appendix A.

Cattle – *Salmonella* spp.

Data from 349 bovine *Salmonella* isolates were submitted for the first year of the pilot project. Currently no antibiotics have bovine-specific clinical breakpoints for *Salmonella*. MIC data for these isolates is in Table 6, Appendix A.

A total of 37 serotypes were represented among the 349 cattle *Salmonella* isolates (Table 7, Appendix A). Overall, the four most prevalent serotypes were Dublin (33.2%), Cerro (18.6%), Typhimurium (10.9%) and Montevideo (8.6%), representing slightly over 71% of all isolates.

Some correlation between serotype and clinical disease was observed. The four most common serotypes associated with diarrhea/enteric infections were Cerro (23.6%), Dublin (16.9%), Typhimurium (14.5%) and Montevideo (11.6%), whereas isolates associated with pneumonia and septicemia were predominantly serotype Dublin (73.1% and 84.8%, respectively). Additional serotypes and clinical symptoms are located in Table 8, Appendix A.

Cattle - *Mannheimia haemolytica*

There were 380 isolates in this dataset. As expected, all isolates were associated with pneumonia or respiratory disease.

Twelve antibiotics on the BOPO6F and BOPO7F plates have breakpoints established specifically for *M. haemolytica* in cattle: ceftiofur, danofloxacin, enrofloxacin, florfenicol, gamithromcin, tildipirosin, tilmicosin, tulathromycin, ampicillin, penicillin, spectinomycin, and tetracycline. These represent 7 different antibiotic classes: cephalosporins (ceftiofur), fluoroquinolones (danofloxacin, enrofloxacin), phenicols (florfenicol), macrolides (gamithromycin, tildipirosin, tulathromycin), penicillins (ampicillin, penicillin), folate pathway inhibitors (spectinomycin), and tetracyclines (tetracycline).

Of the 380 isolates, 65.3% (248/380) were susceptible to all of the above antibiotics; an additional 39 isolates (10.3%) demonstrated resistance to one antibiotic class, and 22 more (5.8%) were resistant to two classes of antibiotics (Table 9, Appendix A). Multi-drug resistance, which is defined as acquired non-susceptibility to at least one agent in three or more antimicrobial categories, was observed in 71 (18.7%) isolates. One isolate of *M. haemolytica* was resistant to all 7 classes and 10 of the 12 antibiotics found on the BOPO plates, with the remaining two antibiotics (macrolides) showing intermediate resistance. Additional information on resistance for individual antibiotic classes is shown in Table 10, Appendix A.

Swine - General

No swine-specific breakpoints for either *E. coli* or *Salmonella* spp. have been established for any of the antibiotics present on the BOPO6F or BOPO7F plates used in Year 1 of the pilot project. Thus, the MIC data presented in Appendix B is displayed as totals for each MIC value only, regardless of therapeutic use in swine.

Swine – *E. coli*

143 *E. coli* isolates from 14 states were submitted in 2018 for the pilot project. MIC data for these isolates is provided in Table 11, Appendix B. Diarrhea/enteric disease accounted for 67.8% (97/143) of the isolates, and pneumonia/respiratory disease were associated with another 23 isolates (16.1%). The remaining diagnoses were abscess/wound infections (6/143, 4.2%), abortion/placentitis (2/143, 1.4%), sepsis/septicemia (5/143, 3.5%), and other or unknown diagnosis (Table 12, Appendix B).

Swine – *Salmonella* spp.

A total of 82 Salmonella isolates and 19 different serotypes were identified from swine. MIC distributions are given in Table 13, Appendix B. Again, salmonella was isolated most frequently from diarrhea/enteric disease cases (50/82, 61%), followed by other/unknown diagnosis (16/50, 19.5%), then pneumonia/respiratory infections (14.6%).

The three most common serotypes overall were 4,[5],12:i:- (28/82, 34.1%), Typhimurium (15/82, 18.3%), and Derby (10/82, 12.2%) (Table 14, Appendix B). Serotype 4,[5],12:i:- was most commonly recovered from cases of diarrhea/enteric disease (20/50, 40%) and pneumonia/respiratory disease (5/12, 31.3%). The remaining clinical symptoms and serotypes are found in Table 15, Appendix B.

Poultry - General

This pilot project accepted data from isolates recovered from domestic chickens, turkeys and ducks only. Similar to swine, no breakpoints for either *E. coli* or *Salmonella* spp. have been established for the antibiotics used to treat poultry diseases, with the exception of enrofloxacin. However, approval for the use of enrofloxacin in poultry was withdrawn by FDA in 2005. Data is provided for all antibiotics on the commercial avian plate, regardless of therapeutic use for the pathogens surveyed.

Poultry – *E. coli*

272 isolates from 20 states are represented in this dataset. 204 isolates (75%) were from chickens, 67 isolates (24.6%) were from turkeys, and 1 isolate (0.4%) was from a domestic duck. MIC data is presented both as aggregate data for chickens and turkeys combined (Table 16, Appendix C), as well as separately for chickens only (Table 17, Appendix C) and turkeys only (Table 18, Appendix C). The single duck isolate submitted during Year 1 was combined with the chicken data.

Diagnoses associated with poultry infections are given in Table 19, Appendix C. For chickens, *E. coli* was most frequently isolated from reproductive tract/yolk sac infections (54/205, 26.3%), followed by *E. coli* infection/septicemia (44/205, 21.5%), and other/unknown diagnosis (40/205, 20.5%). Conversely for turkeys, *E. coli* was most frequently recovered from *E coli* infection/septicemia cases (17/67, 25.4%), other/unknown diagnoses (17/67, 25.4%) and pneumonia (15/67, 22.4%).

Poultry – *Salmonella* spp.

Only 63 *Salmonella* isolates from 12 states were submitted for Year 1 of this project; 52 (82.5%) were from chickens and 11 (17.5%) were from turkeys. MIC information is presented as combined data in Table 20, Appendix C; data for chickens is found in Table 21, Appendix C, and MIC information for turkeys is presented in Table 23, Appendix C.

No discernable trends in diagnosis were identified for cases associated with *Salmonella* for either chickens or turkeys, possibly due to the low numbers of isolates submitted. Because laboratories were unable to obtain a diagnosis for these cases in many instances, they were asked to provide the reason for submission to their facility in the absence of a diagnosis or clinical symptoms. For chickens, 29 isolates (55.8%) were submitted to the diagnostic laboratory for either aerobic culture and sensitivity or serotyping with no accompanying diagnostic information. The remaining 23 isolates from chickens were associated with the following diagnoses; air sacculitis (1), arthritis (1), bacterial infection/septicemia (2), coelomitis (2), colibacillosis (1), coccidiosis (1), hepatitis (1), meningoencephalitis (1), NPIP testing (2), omphalitis (1), opthalmitis (1), osteomyelitis (1), pericarditis (1), salmonellosis (6), and serositis (1) (Table 22, Appendix C). For turkeys, the following general diagnoses were provided; bacterial infection (3), enteritis (3), dehydration/"flushing" in poults (1), omphalitis (1), salmonellosis (1), septicemia (2) (Table 24, Appendix C).

Equine - General

Four antibiotics have breakpoints established for *E. coli* and *Salmonella* spp. from horses. These are amikacin, gentamicin, enrofloxacin, and doxycycline. However, the breakpoint interpretive values for both enrofloxacin are: susceptible ≤0.12 μg/ml; intermediate = 0.25 μg/ml; and resistant ≥0.5 μg/ml, as established by the CLSI in 2017. Conversely, the lowest doxycycline dilution present on the Sensitire™ EQUIN1F plate is 2 μg/ml, and the lowest enrofloxacin dilution is 0.25 μg/ml. Thus, only those isolates with a doxycycline MIC at or above 0.5 μg/ml and an enrofloxacin MIC at or above 4 μg/ml were interpreted as resistant Appendix D. Additionally, separate breakpoints have been established for adult animals and foals for amikacin; information provided in Appendix D is based on adult breakpoints. As with the other animal species, summary MIC data is given for all antibiotics found on the equine AST plates, regardless of therapeutic use for the pathogens surveyed.

Equine – *E. coli*

189 isolates from 25 states are represented in this dataset.

128 (67.7%) *E. coli* isolates were susceptible to the four antibiotics with breakpoints in horses. Overall, resistance to doxycycline was (31.2%, 59/189), resistance to gentamicin was 16.9% (32/189), resistance to enrofloxacin was 10.1% (19/189), and resistance to amikacin was 0.5% (1/189) (Table 25, Appendix D).

Twenty-five of the 128 isolates (13.2%) were resistant to one of the four above antibiotics; of these, 23 were resistant to doxycycline and each of the two remaining isolates were resistant to gentamicin and enrofloxacin, respectively. For the 24 isolates resistant to two antibiotics, 19 were resistant to both doxycycline and gentamicin, and the remaining 5 were resistant to doxycycline and enrofloxacin.

Twelve isolates (6.3%) were classified as multi-drug resistant. Eleven (5.8%) were resistant to three antibiotic classes; all were resistant to doxycycline (tetracycline), gentamicin (aminoglycoside) and

enrofloxacin (fluoroquinolone). One isolate was resistant to all four antibiotics. There were five additional isolates showing intermediate susceptibility to amikacin; three were resistant to the other three antibiotics, one was resistant to doxycycline and gentamicin, and the final isolate was resistant to doxycycline and enrofloxacin.

Reproductive tract infections (metritis, endometritis, placentitis, uterine infection, reproductive failure, and abortion) accounted for approximately half (48.7%, 92/189) of all *E. coli* infections identified in Year 1 of this pilot. The next most common source of *E. coli* was from skin infections/wounds (13.8%, 26/189), then unknown/undetermined infections (11.6%, 22/189). See Table 26, Appendix D for more information on types of infections associated with *E. coli* in horses.

Equine – *Salmonella* spp.

A total of 72 *Salmonella* isolates from 19 states were submitted for Year 1 of this project.

For *Salmonella*, only two antibiotics have breakpoints established in horses; amikacin and gentamicin (Table 27, Appendix D). Thus no analysis for multi-drug resistance was conducted. Sixty-two isolates (86.1%) were sensitive to both antibiotics, 5 isolates (6.9%) were resistant to gentamicin only, and the remaining 5 isolates (6.9%) were resistant to both amikacin and gentamicin.

The vast majority of *Salmonella* isolates were from animals with diarrhea/enteric infection (91.7%, 66/72). However, these cases did not appear to be strongly correlated with a specific serotype, as 25 separate serotypes were identified from these strains. The most common serotype associated with enteric infections in horses was Typhimurium (16.22%, 11/66) followed by serotype Newport (13.2%, 9/66). The entire list of *Salmonella* serotypes are given in Table 28, Appendix D.

The remaining six *Salmonella* isolates and serotypes were associated with the following diagnoses; arthritis (2) [Typhimurium], peritonitis (1) [Typhimurium], ulcerative gastritis /duodenitis (1) [Typhimurium], focal pulmonary arteritis (1) [III 53:z4,z24:-], and abscess (1) [Typhimurium].

Dog - General

More antibiotics have breakpoints established in isolates from dogs compared to any other animal species. There are 13 antibiotics with canine breakpoints for *Enterobacteriaceae/E. coli*, and another 13 antibiotics with canine breakpoints for *Staphylococcus/S. pseudintermedius*.

Dog – *E. coli*

A total of 459 canine *E. coli* isolates from 37 states were submitted for Year 1 of this pilot project. This dataset was subdivided into *E. coli* strains associated with urinary tract infections (UTIs) (293) and those associated with all other infections (166).

Beta-lactamases are enzymes produced by Gram-negative bacteria that mediate resistance to the β-lactam antibiotics used to treat infections caused by these pathogens, including *E. coli*. Extended spectrum β-lactamases (ESBLs) confer resistance to most β-lactam antibiotics, including the newer, extended spectrum (third generation) cephalosporins. For *E. coli*, isolates with growth at or above a MIC of ≥ 8 μg/mL for cefpodoxime or a MIC ≥ 2 μg/mL for ceftazidime may indicate ESBL production, and should be further screened for ESBLs using a supplementary test. While ESBL screening was outside of the scope for this pilot project, isolates meeting this criteria are identified in Appendix E and Appendix F.

Dog – *E. coli* – Urinary tract infections

Five antibiotics have separate breakpoints established for canine UTIs: cefazolin, cephalexin, cefovecin, amoxicillin/clavulanic acid, and ampicillin. However, both amoxicillin/clavulanic acid and ampicillin only have susceptibility breakpoints established. Thus, these two antibiotics were not evaluated when looking at multi-drug resistance.

While ESBL screening was outside the scope of this pilot project, in this dataset there were 59 isolates with MIC values at or above 8 μg/mL for cefpodoxime and 44 isolates with MICs at or above 2 μg/mL for ceftazidime that would be considered candidates for this screening (Table 29, Appendix E).

Almost three-fourths of the UTI isolates (73.7%, 216/293) were susceptible to all antibiotics with resistant breakpoints in dogs. Overall, cephalosporins showed the highest level of resistance, ranging from 19.8% resistance (cefazolin) to 21.8% resistance for cephalexin. Both cefovicin and cefpodoxime had resistance rates of 20.1%. The fluoroquinolone class of antibiotics also showed some resistance, with 15.7% of isolates being resistant to enrofloxacin, marbofloxacin, orbifloxacin and pradofloxacin (Table 29, Appendix E).

Fourteen UTI isolates (4.8%) were classified as multi-drug resistant, or resistant to at least three different classes of antibiotics. One strain was resistant to all four fluoroquinolones, all four cephalosporins, and both aminoglycosides. The other 13 isolates were resistant to all of the cephalosporin and the fluoroquinolone antibiotics, with eight strains also showing resistance to gentamicin [aminoglycoside], and the other five strains being resistant to piperacillin/tazobactam. Further information on the number of isolates resistant to one or more antibiotics is found in Table 30, Appendix E.

Dog – *E. coli* – Non-urinary tract infections

Breakpoints have been established for non-UTI *E. coli* infections for five classes and twelve individual antibiotics in dogs: cefazolin, cephalexin, cefpodoxime, [cepahalosporins] amikacin, gentamicin, [aminoglycosides] amoxicillin/clavulanic acid, piperacillin/tazobactam, [B lactam combination drugs] enrofloxacin, marbofloxacin, orbifloxacin, pradofloxacin [fluoroquinolones] and ampicillin [penicillins] (Table 31, Appendix E).

Of note is that all 166 isolates in this group were resistant to at least one antibiotic, and 74.6% (124/166) were resistant to at least three different antibiotic classes, thus classified as multi drug resistant. Isolates were uniformly resistant to amoxicillin/clavulanic acid and ampicillin (100% and 99.4% resistance rates, respectively), and resistance to cephalexin was 72.9%. The other two cephalosporin drugs with established breakpoints also showed elevated resistance levels; cefazolin with 29.6% resistant, and cefpodoxime with 25.9% resistant. Fluoroquinlone resistance was somewhat lower, with 16.3% of isolates resistant to enrofloxacin, marbofoxacin, and pradofloxacin, and 16.9% resistant to orbifloxacin. Screening for ESBL would be indicated for 43 isolates with MIC values at or > 8 μg/mL for cefpodoxime, and 33 isolates with MIC values ≥ 2 μg/mL for ceftazidime.

Twenty-four (24) isolates were resistant to 8 or more antibiotics; all were resistant to all three cephalosproins and all four fluoroquinolones, plus amoxicillin/clavulanic acid and ampicillin. Nine of these 24 isolates were also resistant to gentamicin, and two were resistant to piperacillin/tazobactam (Table 32, Appendix E). These isolates were recovered from a variety of infections; granulomatous colitis

(1), intestinal biopsy/diarrhea (1), pneumonia/respiratory infection (4), abscess/wound (6), ear infection (3), vaginal infection (2), peritonitis (1), peritoneal fluid (2), cholecystitis (1), and unknown (3).

Approximately 30% of the 166 non-UTI *E. coli* isolates were associated with abscess/skin/wound infections, and another 16.9% (28/166) were from ear infections (Table 33, Appendix E). Diarrhea/enteric infections were the next largest category, at 10.2%.

Dog – *Salmonella* spp.

Only 14 Salmonella isolates from 10 states were submitted for Year 1 of this project.

There are six antibiotics with Enterobacteriaceae breakpoints established for dogs; these are gentamicin, piperacillin/tazobactam, enrofloxacin, marbofloxacin, orbifloxacin and pradofloxacin.

Thirteen of the 14 *Salmonella* isolates from dogs were sensitive to all of these antibiotics, with the remaining isolate being resistant to piperacillin/tazobactam (Table 34, Appendix E). These isolates were recovered from cases of diarrhea/enteric infections (6), undetermined (3), wound infections (2), endocarditis (1), septicemia (1), and one urinary tract infection. No discernable correlation between diagnosis and serotypes were observed, with 11 different serotypes associated with these cases (Table 35, Appendix E).

Dog – *Staphylococcus intermedius* group

The *Staphylococcus intermedius* group, and specifically *S. pseudintermedius*, predominantly colonizes dogs and cats and can cause serious infections. Criteria for identifying the bacteria within this group differed across participating laboratories, with some laboratories reporting isolates as belonging to the *S. intermedius* group, and other laboratories reporting individual species (*S. intermedius*, *S. pseudintermedius* or *S. delphini).* Thus, for the purposes of this pilot, all isolates were identified as belonging to the *Staphylococcus intermedius* group. 492 canine isolates from 35 states are represented in this dataset. As with *E. coli*, isolates were separated into those associated with urinary tract infections (78), and all other isolates (414).

When performing a routine antibiotic sensitivity panel, oxacillin resistance is often used as an indicator for identifying staphylococcal isolates which may carry the *mecA* gene associated with methicillin resistance. If resistant, the isolate is then considered to be resistant to all β-lactam antibiotics. However, the 2018 version of CLSI's Vet08 document does not provide a breakpoint for oxacillin for either dogs or cats. Thus, the human breakpoint value of ≥0.5 μg/mL was used as the cutoff for resistance for isolates for both the canine and feline datasets.

Dog – *S. intermedius* group – Urinary tract infections

Seventy-eight (78) canine staphylococcal UTI isolates were derived from animals in 16 different states. Oxacillin resistance was also evaluated for urinary tract infection isolates, using the human breakpoint values to separate this group into oxacillin resistant (OX^R) and oxacillin sensitive (OX^S) strains.

Antibiotics [and class] with breakpoints established for canine urinary tract infection isolates are as follows: cefazolin [cephalosporin], amikacin [aminoglycoside], amoxicillin/clavulanic acid [beta lactam combo], enrofloxacin, marbofloxacin, and pradofloxacin [fluoroquinolones]. However, no breakpoints for intermediate or resistant interpretations have been established for amoxicillin/clavulanic acid, so resistance percentages for this antibiotic are not reported. Additionally, resistance to amikacin may be

under-reported due to an inadequate range of dilutions on the sensitivity plate, which does not cover the canine sensitive or intermediate breakpoints at or below 16 μg/mL.

Dog – *S. intermedius* group – Urinary tract infections – Oxacillin sensitive

In total, 68/78 (87.2%) isolates associated with urinary tract infections were susceptible to oxacillin. These isolates were uniformly susceptible to cefazolin, and amoxicillin/clavulanic acid, and only 5.9% of the isolates were resistant to enrofloxacin, marbofloxacin and pradofloxacin (Table 36, Appendix E). This group of isolates also appears to have no resistance to amikacin, with the caveat regarding the dilution scheme noted above. No multi drug resistant strains were identified in this group.

Dog – *S. intermedius* group – Urinary tract infections – Oxacillin resistant

Ten (12.8%) of the *Staphylococcus* UTI isolates were oxacillin resistant. Although only a very small number of isolates were evaluated, high levels of resistance were similarly noted in these isolates, with all of the fluoroquinolone antibiotics showing resistance rates of 50% or higher (Table 37, Appendix E). Multi drug analysis was not performed in this subset, as only two classes of antibiotics (fluoroquinolones and β lactam inhibitor combination drug) have breakpoints established for dog urinary tract infections.

Dog – *S. intermedius* group – Non-urinary tract infections

84.4% (415/492) of the canine *S. intermedius* isolates submitted for Year 1 of this pilot were associated with infections other than UTIs.

For dogs, there are fourteen antibiotics from seven antibiotic classes with *Staphylococcus spp*. or *S. pseudintermedius* breakpoints. These are amikacin [aminoglycoside], amoxicillin/clavulanic acid [β lactam combination], cefazolin, cephalothin, cefovecin, cefpodoxime [cephalosporins], enrofloxacin, marbofloxacin, pradofloxacin [fluoroquinolones], clindamycin [lincosamides], ampicillin [penicillin], doxycycline, minocycline, and tetracycline [tetracyclines]. The non-UTI staphylococcal isolates were also divided into OX^S strains (64.6%, 268/415) and OX^R strains (33.7%, 147/415) based on human oxacillin breakpoint values, with each group being analyzed separately for multi-drug resistance.

Dog – *S. intermedius* group – Non-urinary tract infections – Oxacillin sensitive

All 268 isolates were susceptible to all four cephalosporin antibiotics and to amoxicillin/clavulanic acid (Table 38, Appendix E). Additionally, only one isolate demonstrated resistance to amikacin. However, resistance to this antibiotic may be under-reported due to an inadequate range of dilutions on the AST plate, which does not cover the canine sensitive or intermediate breakpoints at or below 16 μg/mL. Conversely, 39.2% of all isolates were resistant to ampicillin, and 28.7% were resistant to doxycycline and tetracycline. Minocycline resistance was only slightly less, at 26.5% resistance.

24 isolates (8.9%, 24/268) were classified as multi-drug resistant. Resistance to fluoroquinolones and tetracyclines were routinely observed, with variable resistance to clindamycin [lincosamide] and ampicillin [penicillin] (Table 39, Appendix E). The isolates in this group were predominantly associated with skin/wound abscess infections (54.9%, 147/268) and otitis/ear infections (22.8%, 61/268). (Table 40, Appendix E).

Dog – *S. intermedius* group – Non-urinary tract infections – Oxacillin resistant

The remaining 146 canine *S. intermedius* group isolates (35.2%, 146/415) were oxacillin resistant. As with the oxacillin sensitive subgroup, most isolates were associated with abscess/wound/skin infections (52.1%, 76/146) and otitis/ear infections (28.8%, 42/146) (Table 43, Appendix E). However, resistance to

other antibiotics/antibiotic classes were substantially higher, with resistance rates to other antibiotics ranging from a low of 66.4% (pradofloxacin) to a high of 78.1% (doxycycline and tetracycline) (Table 41, Appendix E). Since pradofloxacin is not approved for use in dogs in the U.S., it is assumed this high level of resistance has been acquired through genetic factors conferring resistance to fluoroquinolone antibiotics in general.

Of the 146 OX^R isolates, 83 (56.9%) were multi-drug resistant. 80/83 (96.4%) were resistant to clindamycin [lincosamide], all of the fluoroquinolone and all of the tetracycline antibiotics. Additional information on individual antibiotic and antibiotic class resistance is detailed in Table 42, Appendix E.

Cat - General

Data is provided for all antibiotics found on the COMPGN1F and COMPGP1F plates, regardless of therapeutic use for the pathogens surveyed. Isolates associated with urinary tract infections were identified and analyzed separately from the remaining isolates. Additional information on feline MIC distribution data can be found in Appendix F.

Cat – *E. coli*

Susceptibility testing data encompassing 266 isolates from 25 states were submitted during Year 1 of this pilot project. Of those, 198 were associated with urinary tract infections (UTIs) and urinary tract disease, while the remaining 68 isolates were from respiratory, wound, and skin/soft tissue infections.

Cat – *E. coli* – Urinary tract infections

Three antibiotics have breakpoints established for feline UTI infections; cefovecin, amoxicillin/clavulanic acid and ampicillin. For the 198 isolates in this category, all (100%) were resistant to amoxicillin/clavulanic acid, and 99% (196/198) were resistant to ampicillin. Sixteen isolates (8.1%) were resistant to cefovecin, and thirteen (6.6%) were resistant to all three antibiotics (Table 44, Appendix F).

While ESBL screening was outside of the scope for this pilot project, there were 19 and 13 isolates with MIC values at or above 8 μg/mL for cefpodoxime and 2 μg/mL for ceftazidime, respectively, that would be considered candidates for this screening; these are highlighted in blue in Table 44, Appendix F.

Cat – *E. coli* – Non-urinary tract infections

In addition to amoxicillin/clavulanic acid and ampicillin, four fluoroquinolone antibiotics also have breakpoints established for isolates from cats for use in skin and soft tissue infections. These are enrofloxacin, marbofrloxacin, orbifloxacin and pradofloxadin. Conversely, cefovecin does not have feline-specific breakpoints for isolates from these body sites.

Similar to above, the 68 feline *E. coli* isolates from non-UTI infections were 100% resistant to both ampicillin and amoxicillin/clavulanic acid (Table 45, Appendix F). Fluoroquinolone resistance was significantly lower at 1.5% to 2.9%, with only 1-2 isolates demonstrating resistance to each of the four fluoroquinolone antibiotics. Ten isolates had MIC values for cefpodoxime that met the criteria for ESBL testing, and nine isolates met this criteria for ceftazidime.

Two isolates were classified as multi-drug resistant. One isolate was resistant to all four fluoroquinolone drugs plus ampicillin and amoxicillin/clavulanic acid, from a case with a diagnosis of cholangitis, or inflammation of the bile duct. The other MDR isolate, recovered from a mastitis case, was resistant to orbifloxacin, had intermediate resistance to enrofloxacin and pradofloxacin, and was sensitive only to

marbofloxacin. A final isolate that was not classified as multi-drug resistant was sensitive to both marbofloxacin and pradofloxacin, with intermediate resistance to enrofloxacin and orbifloxacin, and resistance to ampicillin and amoxicillin/clavulanic acid. This isolate was from a perianal abscess.

The primary diagnoses associated with feline *E. coli* non-UTI infections were skin/wound infections (20.6%, 14/68), pneumonia/respiratory infections (17.6%, 12/68), and peritonitis/parenchymous organ infections (16.2%, 11/68). Additional clinical symptoms/diagnoses are reported in Table 46, Appendix F.

Cat – *Salmonella* spp.

Only four Salmonella isolates from three states were submitted for Year 1 of this project. The MIC distributions of these isolates are in Table 47, Appendix F.

Final diagnosis for these isolates were salmonellosis (3) and lymphadenitis (1). Serotypes 4, [5], 12:i:- (2) and Enteritidis (2) were identified.

Cat – *Staphylococcus intermedius* group

This dataset contained a total of 56 isolates from 14 states; 14 were associated with urinary tract infections, and the remaining 42 were from other body sites.

Cat – *S. intermedius* group – Urinary tract infections

All 14 feline isolates were sensitive to oxacillin using the human cutoff value of ≤ 0.25 μg/mL. In this group, one isolate was identified as *S. delphini*, which is a member of the *S. intermedius* group. Only two antibiotics have breakpoints established for *Staphylococcus spp*. UTIs in cats; these are amoxicillin/clavulanic acid and ampicillin. Twelve of the fourteen isolates were susceptible to both ampicillin and amoxicillin/clavulanic acid, and the remaining two (14.3%) were resistant only to ampicillin (Table 48, Appendix F).

Cat – *S. intermedius* group – Non-urinary tract infections

For non-urinary tract infections, five antibiotics have breakpoints for *Staphylococcus spp*. established in cats. These are amoxicillin/clavulanic acid, enrofloxacin, marbofloxacin, pradofloxacin and ampicillin.

Cat – *S. intermedius* group – Non-urinary tract infections – Oxacillin sensitive

A total of 42 feline non-UTI *Staphylococcus* isolates were submitted during Year 1 of the pilot. Of these, 23 (54.8%) were considered sensitive to oxacillin (Table 49, Appendix F). Within the oxacillin-sensitive subgroup, 22/23 isolates were susceptible to amoxicillin/clavulanic acid, with the remaining isolate showing intermediate susceptibility. Eleven strains were susceptible to all five antibiotics listed above. Two of the 23 isolates (8.7%) were resistant to all three fluoroquinolone antibiotics, and seven isolates (30.4%) were resistant to ampicillin. Infections associated with the two fluoroquinolone resistant strains were ear infection (1) and suppurative inflammation (1). The seven isolates showing resistance to ampicillin were associated with sinus infection (1), ear infection (1), purulent nasal discharge (1), pyoderma (2), mammary gland infection (1) and pinna cartilage infection (1) (Table 50, Appendix F).

Cat – *S. intermedius* group – Non-urinary tract infections – Oxacillin resistant

The remaining 19 isolates associated with non-urinary tract infections were classified as oxacillin resistant (OX^R). Using the human clinical breakpoint of ≥ 0.5 μg/mL for resistant isolates, the following antibiotics would also be reported as resistant: cefazolin, cephalothin, cefovecin, cefpodoxime, amoxicillin/clavulanic acid, imipenem, ampicillin, and penicillin.

Thus, only results for enrofloxacin, marbofloxacin and pradofloxacin are discussed. Across the fluoroquinolone antibiotics, 63.2% of the isolates were resistant to enrofloxacin, 68.4% were resistant to marbofloxacin, and 52.6% were resistant to pradofloxacin (Table 51, Appendix F).

Ten of the OX^R isolates were resistant to all three fluoroquinolones; these were associated with abscess/skin/wound infections (8), rhinitis (1), and an unknown infection (1) (Table 52, Appendix F). Two more isolates, recovered from an ear infection and a skin infection, were resistant to both enrofloxacin and marbofloxacin, with intermediate susceptibility to pradofloxacin. One isolate (ear infection) was resistant to marbofloxacin, had intermediate susceptibility to enrofloxacin, and was sensitive to pradofloxacin. The final three strains were susceptible to marbofloxacin and pradofloxacin, with intermediate resistance to enrofloxacin.

Epidemiological Cutoff Values

Epidemiological cutoff values, or ECVs, distinguish between organisms with and without phenotypically expressed resistance mechanisms for a bacterial species and a corresponding antibiotic. Generally, these two groups are termed "non-wild type" and "wild type" respectively. This is in contrast to a clinical breakpoint, which defines an isolate as "resistant" or "susceptible" to a particular drug. Thus, it is possible for a "non-wild type" isolate to also be clinically "susceptible" to an antibiotic, so ECVs should never be used to guide therapy, and are only used to detect isolates with acquired resistance to an antibiotic.

Several U.S. and international standards organizations determine ECVs for monitoring antimicrobial resistance. In the U.S., the Food and Drug Administration (FDA), and the Clinical Standards Laboratory Institute (CLSI) perform this function, and within the European Union, the European Committee on Antimicrobial Susceptibility Testing (EUCAST) sets ECVs. A publicly available database for identifying ECVs is available through the EUCAST website (https://mic.eucast.org/Eucast2/). This website was used to identify ECVs that would be applicable to the pathogens surveyed in Year 1 of this pilot; those antibiotics with established ECVs are provided in Appendix G.

For *E. coli* isolates across all animal species, all were classified "non-wild type" for two antibiotics (ceftazidime and imipenem) (Table 53, Appendix G). Similarly, only 24.5% of *Salmonella* isolates were classified as "wild type" (Table 54, Appendix G). Only two antibiotics have ECVs established for *M. haemolytica,* florfenicol and tetracycline. The percentage of isolates classified as "wild-type" was 86.8% and 67.4%, respectively (Table 55, Appendix G).

Three antibiotics have established ECVs for Staphyloccus intermedius group isolates; vancomycin, erythromycin and chloramphenicol (Table 56, Appendix G). For erythromycin, 65.3% of isolates were classified as "wild type". For chloramphenicol, this number was 91.4% and for vancomycin it was 99.6%

References:

1. Clinical and Laboratory Standards Institute (CLSI). 2018. *Performance Standards for Antimicrobial Disk and Dilution Susceptibility Tests for Bacteria Isolated from Animals.* 4th ed. CLSI supplement VET08. Clinical and Laboratory Standards Institute, 950 West Valley Road, Suite 2500, Wayne, Pennsylvania 19087 USA.

2. Magiorakos, A.-O., *et. al*. 2012. Multidrug-resistant, extensively drug-resistant and pandrug-resistant bacteria: an international expert proposal for interim standard definitions for acquired resistance. *Clin Microbiol Infect*. 18:268-281.

3. Weese, J.S., and E. van Duijkeren. 2010. Methicillin-resistant *Staphylococcus aureus* and *Staphylococcus pseudintermedius* in veterinary medicine. *Vet. Microbiol*. 140(3-4):418-429.

APPENDIX A: Cattle MIC Distributions, Salmonella Serotypes and Clinical Symptoms

CATTLE – *E. COLI* INFECTIONS

TABLE 4. MIC DISTRIBUTION FOR E. COLI ISOLATES RECOVERED FROM CATTLE.

Antibiotic class	Antibiotic \ MIC value (µg/mL)	<=0.12	<=0.25	0.25	<=0.5	0.5	<=1	1	>1	<=2	2	>2	<=4	4	>4	<=8	8	>8	16	>16	32	>32	64	>64	<=256	>256	Total Isolates[§]	% R*
3rd gen cephalosporin	Ceftiofur**		76			159		4			5			6			30	92									372	
aminocyclitol	Spectinomycin															18			205		28		16	105			372	
aminoglycoside	Gentamicin						305				6			1			4		7	49							372	
aminoglycoside	Neomycin												245				3		5		14	105					372	
fluoroquinolone	Danofloxacin	279		2		8		3	80		0																372	
fluoroquinolone	Enrofloxacin	274		8		4		6			2	78															372	
folate pathway antagonist	Sulphadimethoxine																								122	250	372	
folate pathway antagonist	Trimethoprim/sulfamethoxazole[†]									234		138															372	
lincosamide	Clindamycin		0			0		3			0			0			1			368							372	
macrolides	Gamithromycin						1				3			14			53	15									86	
macrolides	Tildipirosin						1				8			50			23	0	2	2							86	
macrolides	Tilmicosin									0			0				2		1	85	22		171	91			372	
macrolides	Tulathromycin						0				8			49		76	162		63		2		2	10			372	
macrolides	Tylosin				0			0			1			0	1		0		1		0	369					372	
penicillin	Ampicillin[§]		0			0		7			73			88			4			200							372	
penicillin	Penicillin	0		0		0		0			0			0			2	370									372	
phenicol	Florfenicol		0			0		3			41			155			31	142									372	
pleuromutilin	Tiamulin						0				0			1			0		2		15	354					372	
tetracycline	Chlortetracycline				2			13			39			32			9	191									286	
tetracycline	Oxytetracycline				1			25			52			6			1	201									286	
tetracycline	Tetracycline				0			10			13			0			1	62									86	

Bovine-specific interpretive criteria are indicated for selected antibiotics. Green shaded cells = sensitive, yellow shaded cells = intermediate and red shaded cells = resistant. Interpretive values are based on CLSI Vet08, 4th ed. (2018)

[§] Total number of isolates for each antibiotic reflect a combination of the BOPO6F and BOPO7F plates. Not all antibiotics in the table are present on both plates, leading to differences in total numbers of isolates.

* % R = percentage of resistant isolates.

**Ceftiofur breakpoints have been established for mastitis cases only for *E. coli* infections in cattle. Because there were only 5/372 isolates in this table that were reported to be from mastitis cases, overall % resistance is not reported.

[§] Ampicillin breakpoints have been established for metritis cases only for *E. coli* infections in cattle. Because there were only 3/372 isolates in this table that were reported to be from metritis cases, overall % resistance is not reported.

[†]Trimethoprim/sulfamethoxazole concentration on plate = 2/38 µg/mL.

TABLE 5. CLINICAL SYMPTOMS AND DIAGNOSES ASSOCIATED WITH BOVINE E. COLI INFECTIONS.

Clinical symptoms and/or diagnosis	COUNT	%
DIARRHEA, ENTERIC INFECTIONS	217	58.3%
SEPSIS, SEPTICEMIA	40	10.8%
PNEUMONIA, RESPIRATORY INFECTIONS	36	9.7%
UNDETERMINED, DIAGNOSIS NOT PROVIDED	23	6.2%
OTHER*	16	4.3%
ABORTION, NEONATAL DEATH	14	3.8%
NEPHRITIS, HEPATITIS, PERITONITIS	9	2.4%
MASTITIS	5	1.3%
UTERINE INFECTIONS, METRITIS	3	0.8%
WOUNDS, JOINT INFECTIONS	3	0.8%
URINARY TRACT INFECTIONS, CYSTITIS	3	0.8%
ENCEPHALITIS	3	0.8%
TOTAL	372	

*Other diagnoses = esophagitis (1), lymphoma (1), ruptured penis (1), hepatic iron/copper accumulation (1), attaching and effacing *E. coli* (1), serositis/polyserositis (2), anaphylaxis (2), hepatocellular degeneration/necrosis (1), respiratory acidosis (1), GTI (1), myocardial necrosis (1), *Mycopasma weyanii* infection (1), fatty liver (1), and gastric torsion (1)

CATTLE – *SALMONELLA* SPP. INFECTIONS

TABLE 6. MIC DISTRIBUTION FOR SALMONELLA ISOLATES RECOVERED FROM CATTLE.

antibiotic class	MIC value (µg/mL) / Antibiotic	<=0.12	<=0.25	0.25	<=0.5	0.5	<=1	1	>1	<=2	2	>2	<=4	4	<=8	8	>8	16	>16	32	>32	64	>64	<=256	>256	Total Isolates§	% R*
3rd gen cephalosporin	Ceftiofur		3			63		136			5			2		25	115									349	
aminocyclitol	Spectinomycin														3			84		180		52	30			349	
aminoglycoside	Gentamicin						331				11			2		1		2	2							349	
aminoglycoside	Neomycin												276			3		2		1	67					349	
fluoroquinolone	Danofloxacin	294		9		27		16	3		0															349	
fluoroquinolone	Enrofloxacin	292		8		31		7			10	1														349	
folate pathway antagonist	Sulphadimethoxine																							132	217	349	
folate pathway antagonist	Trimethoprim/sulfamethoxazole†									321		28														349	
lincosamide	Clindamycin		0			0		1			0			0		0			348							349	
macrolides	Gamithromycin						0				1			41		51	5									98	
macrolides	Tildipirosin						0	0			0			8		47		36	7							98	
macrolides	Tilmicosin									0			0			0		1	97	0		34	217			349	
macrolides	Tulathromycin						0				0			15	54	136		106		34		0	4			349	
macrolides	Tylosin				0			0			0			1		1		0		1	346					349	
Penicillins	Ampicillin		1			15		155			25			2		0			151							349	
Penicillins	Penicillin	1		0		0		1			0			8		157	182									349	
phenicol	Florfenicol		0			1		11			98			87		6	146									349	
pleuromutilin	Tiamulin						0				1			0		0		1			347					349	
tetracycline	Chlortetracycline				6			43			64			29		2	107									251	
tetracycline	Oxytetracycline				14			74			55			0		0	108									251	
tetracycline	Tetracycline				19			12			8			0		0	59									98	

§ Total number of isolates for each antibiotic reflect a combination of the BOPO6F and BOPO7F plates. Not all antibiotics in the table are present on both plates, leading to differences in total numbers of isolates.

* % R = percentage of resistant isolates. No antibiotic interpretive breakpoints have been established for *Salmonella* isolates from cattle.

TABLE 7. OVERALL PREVALENCE OF BOVINE SALMONELLA SEROTYPES.

Cattle – Salmonella serotype, overall											
Salmonella Serotype	count	%	Salmonella Serotype	count	%	Salmonella Serotype	count	%	Salmonella Serotype	count	%
Dublin	116	33.2%	Kentucky	5	1.4%	"O" group B, "H"I, monophasic	1	0.3%	Liverpool	1	0.3%
Cerro	65	18.6%	Uganda	4	1.1%	18:Nonmotile	1	0.3%	Oranienburg	1	0.3%
Typhimurium	38	10.9%	Mbandaka	3	0.9%	Adelaide	1	0.3%	Ruiru	1	0.3%
Montevideo	30	8.6%	Meleagridis	3	0.9%	Braenderup	1	0.3%	Rough O:l,z13:1,5	1	0.3%
Give	12	3.4%	Muenchen	3	0.9%	Bredeney	1	0.3%	Saintpaul	1	0.3%
Heidelberg	11	3.2%	Agona	2	0.6%	Cubana	1	0.3%	Senftenberg	1	0.3%
Newport	11	3.2%	Altona	2	0.6%	Derby	1	0.3%	Worthington	1	0.3%
Anatum	8	2.3%	Bovismorbificans	2	0.6%	Ealing	1	0.3%	TOTAL	349	
Muenster	7	2.0%	Kiambu	2	0.6%	Idikan	1	0.3%			
4,[5],12:i:-	6	1.7%	Schwarzengrund	2	0.6%	Infantis	1	0.3%			

TABLE 8. FREQUENCY OF BOVINE SALMONELLA SEROTYPES ASSOCIATED WITH CLINICAL SYMPTOMS/DIAGNOSES.

Cattle – Salmonella serotype, sorted by clinical symptoms/diagnosis

DIARRHEA/ENTERIC DISEASE

SEROTYPE	COUNT	%
Cerro	57	23.6%
Dublin	41	16.9%
Typhimurium	35	14.5%
Montevideo	28	11.6%
Give	12	5.0%
Newport	11	4.5%
Heidelberg	8	3.3%
Anatum	5	2.1%
Kentucky	5	2.1%
Muenster	5	2.1%
4,[5],12:i:-	4	1.7%
Mbandaka	3	1.2%
Meleagridis	3	1.2%
Uganda	3	1.2%
Agona	2	0.8%
Muenchen	2	0.8%
Schwarzengrund	2	0.8%

DIARRHEA/ENTERIC DISEASE, continued

SEROTYPE	COUNT	%
Altona	1	0.4%
"O" group B, "H"I, monophasic	1	0.4%
18:Nonmotile	1	0.4%
Adelaide	1	0.4%
Anatum var 15+	1	0.4%
Bovismorbificans	1	0.4%
Braenderup	1	0.4%
Bredeney	1	0.4%
Ealing	1	0.4%
Idikan	1	0.4%
Infantis	1	0.4%
Kiambu	1	0.4%
Liverpool	1	0.4%
Ruiru	1	0.4%
Saintpaul	1	0.4%
Worthington	1	0.4%
TOTAL	**242**	

SEPTICEMIA

SEROTYPE	COUNT	%
Dublin	56	84.8%
4,[5],12:i:-	2	3.0%
Cerro	2	3.0%
Altona	1	1.5%
Cubana	1	1.5%
Derby	1	1.5%
Heidelberg	1	1.5%
Muenchen	1	1.5%
Uganda	1	1.5%
TOTAL	**66**	

OTHER*

SEROTYPE	COUNT	%
Muenster	2	40%
Anatum	1	20%
Cerro	1	20%
Senftenberg	1	20%
TOTAL	**5**	

PNEUMONIA

SEROTYPE	COUNT	%
Dublin	19	73.1%
Heidelberg	2	7.7%
Anatum	1	3.8%
Bovismorbificans	1	3.8%
Cerro	1	3.8%
Kiambu	1	3.8%
Oranienburg	1	3.8%
TOTAL	**26**	

ABORTION/PLACENTITIS

SEROTYPE	COUNT	%
Cerro	4	40%
Typhimurium	3	30%
Montevideo	2	20%
Rough O:l,z13:1,5	1	10%
TOTAL	**10**	

*OTHER diagnoses = acute selenium toxicity (1) and Salmonella surveillance (4).

CATTLE – *MANNHEIMIA HAEMOLYTICA*

TABLE 9. MIC DISTRIBUTION FOR MANNHEIMIA HAEMOLYTICA ISOLATES RECOVERED FROM CATTLE.

antibiotic class	MIC value (µg/mL) / Antibiotic	<=0.12	<=0.25	0.25	<=0.5	0.5	<=1	1	>1	<=2	2	>2	<=4	4	<=8	8	>8	16	>16	32	>32	64	>64	<=256	>256	Total Isolates[§]	% R*
3rd gen cephalosporin	**Ceftiofur**		367			8		2			0			2		1	0									380	0.3%
aminoglycoside	**Gentamicin**						58				234			29		4		3	52							380	
aminoglycoside	**Neomycin**												199			77		3		4	97					380	
aminoglycoside	**Sulphadimethoxine**																							247	133	380	
fluoroquinolone	**Danofloxacin**	273		11		13		5	78																	380	21.8%
fluoroquinolone	**Enrofloxacin**	273		11		15		6			4	71														380	19.7%
folate pathway antagonist	**Spectinomycin**														8			88		215		6	64			380	16.6%
folate pathway antagonist	**Trimethoprim/sulfamethoxazole[†]**									373		7														380	
lincosamide	**Clindamycin**		3			0		3			2			13		193		99	66							379	
macrolides	**Gamithromycin**						72				5			2		1	12									92	13.0%
macrolides	**Tildipirosin**						57				19			4		2		1	9							92	1.1%
macrolides	**Tilmicosin**									6			152	46		63		25	14	9		10	55			380	23.2%
macrolides	**Tulathromycin**						10				31			121	78	52		10		8		6	64			380	18.4%
macrolides	**Tylosin**				2			1			1			1		2		9		131	233					380	
Penicillins	**Ampicillin**		301			19		4			2			2		4		9	39							380	20.8%
Penicillins	**Penicillin**	153		114		34		21			3			3		4	48									380	20.8%
phenicol	**Florfenicol**		22			193		96			19			3		4	43									380	11.3%
pleuromutilin	**Tiamulin**				3			1			4			19		150		170		30	3					380	
tetracycline	**Chlortetracycline**				95			90			21			27		32	23									288	
tetracycline	**Oxytetracycline**				151			27			4			3		14	89									288	
tetracycline	**Tetracycline**				57			4			1			11		5	14									92	20.7%

Bovine-specific interpretive criteria are indicated for selected antibiotics. Green shaded cells = sensitive, yellow shaded cells = intermediate and red shaded cells = resistant. Interpretive values are based on CLSI Vet08, 4th ed. (2018)

[§] Total number of isolates for each antibiotic reflect a combination of the BOPO6F and BOPO7F plates. Not all antibiotics in the table are present on both plates, leading to differences in total numbers of isolates.

* % R = percentage of resistant isolates.

[†]Trimethoprim/sulfamethoxazole concentration on plate = 2/38 µg/mL.

TABLE 10. ANTIBIOTIC RESISTANCE ANALYSIS FOR BOVINE MANNHEIMIA HAEMOLYTICA ISOLATES.

		Number of resistant isolates by antibiotic class and individual antibiotic											
		CEPHALO-SPORIN	FOLATE PATHWAY INHIBITOR	FLUOROQUINOLONE		MACROLIDE				PENICILLIN		PHENICOL	TETRACYCLINE
No. of antibiotic resistant phenotypes per isolate	No. isolates	Ceftiofur No. resistant	Spectinomycin No. resistant	Danofloxacin No. resistant	Enrofloxacin No. resistant	Gamithromycin* No. resistant	Tilmicosin No. resistant	Tildipirosin No. resistant	Tulathromycin* No. resistant	Ampicillin No. resistant	Penicillin No. resistant	Florfenicol No. resistant	Tetracycline* No. resistant
11	5	0	5	5	5	5	5	5	5	5	5	5	5
10	2	1	2	2	2	1	1 (1 intermediate susceptibility)	2	2	2	2	1	2
9	3	0	3	3	3	3	3	2	3	2	1 (2 intermediate susceptibility)	2	2
8	19	0	19	19	19	1	19	0	19	19	19	18	1
7	16	0	14	16	16	1	16	0	16	14	15 (1 intermediate susceptibility)	3 (2 intermediate susceptibility)	1
6	10	0	6	10	9 (1 intermediate susceptibility)	0	10	0	8 (2 intermediate susceptibility)	5	4 (6 intermediate susceptibility)	9	0
5	11	0	7	10	10	0	11	0	10 (1 intermediate susceptibility)	2	3 (5 intermediate susceptibility)	2 (1 intermediate susceptibility)	0
4	9	0	0	6	5 (1 intermediate susceptibility)	1	7	1	2 (3 intermediate susceptibility)	5	4 (2 intermediate susceptibility)	4	0 (1 intermediate susceptibility)
3	14	0	5 (1 intermediate susceptibility)	5 (3 intermediate susceptibility)	4 (3 intermediate susceptibility)	0	8 (3 intermediate susceptibility)	0	4 (1 intermediate susceptibility)	8	8	3	2
2	17	0	1 (1 intermediate susceptibility)	4 (1 intermediate susceptibility)	1 (4 intermediate susceptibility)	0	1 (9 intermediate susceptibility)	0	1	12	11 (1 intermediate susceptibility)	0	3
1	26	0	2 (2 intermediate susceptibility)	3 (1 intermediate susceptgibility)	1 (4 intermediate susceptibility)	0	7 (1 intermediate susceptibility)	0	0	5	7 (2 intermediate susceptibility)	0	3
0	248	0	0 (2 intermediate susceptibility)	0 (7 intermediate susceptibility)	0 (7 intermediate susceptibility)	0 (9 intermediate susceptibility)	0	0	0	0	14 intermediate susceptibility)	0	0 (2 intermediate susceptibility)
TOTAL	380	1	64	83	75	12	88	10	70	79	79	47	19

*gamithromycin, tulathromycin and tetracycline are only present on BOPO7F plates; total number of isolates surveyed for these antibiotics = 92

APPENDIX B: Swine MIC Distributions, Salmonella Serotypes and Clinical Symptoms

SWINE – *E. COLI* INFECTIONS

TABLE 11. MIC DISTRIBUTION FOR E. COLI ISOLATES RECOVERED FROM SWINE.

antibiotic class	MIC value (µg/mL) / Antibiotic	<=0.12	<=0.25	0.25	<=0.5	0.5	<=1	1	>1	<=2	2	>2	<=4	4	>4	<=8	8	>8	16	>16	32	>32	64	>64	<=256	>256	Total Isolates[§]	% R*
3rd gen cephalosporin	Ceftiofur		25			63		4			4			1			14	32								143	
lincosamide	Clindamycin		0			0		1			0			0			0			142						143	
aminoglycoside	Gentamicin						92				4			1			6		6	34						143	
aminoglycoside	Neomycin												100				3		2		12	26				143	
fluoroquinolone	Danofloxacin	95		6		12		2	28		0															143	
fluoroquinolone	Enrofloxacin	95		5		10		5			15	13														143	
folate pathway antagonist	Spectinomycin															3			67		11		10	52			143	
folate pathway inhibitor	Sulphadimethoxine																								52	91	143	
macrolides	Gamithromycin						2				1			16			38	14								71	
macrolides	Tiamulin						0				0			0			0		1		7	135				143	
macrolides	Tildipirosin						1				5			43			16		1	5						71	
macrolides	Tilmicosin												0	1			0		0	70	4		42	26			143	
macrolides	Tulathromycin						0				0			10		59	36		24		1		3	10			143	
macrolides	Tylosin				0			0			0			0	1		0		1		0	141					143	
Penicillin	Ampicillin		1			0		4			16			17			0			105							143	
Penicillin	Penicillin	1		0		0		0			0			0			0	142									143	
phenicol	Florfenicol		1			0		0			18			75			19	30									143	
pleuromutilin	Trimethoprim/sulfamethoxazole[†]									97		46															143	
tetracycline	Chlortetracycline				0			3			6			1			3	59									72	
tetracycline	Oxytetracycline				0			6			6			0			0	60									72	
tetracycline	Tetracycline				0			6			5			0			0	60									71	

[§] Total number of isolates for each antibiotic reflect a combination of the BOPO6F and BOPO7F plates. Not all antibiotics in the table are present on both plates, leading to differences in total numbers of isolates.

* % R = percentage of resistant isolates. No antibiotic interpretive breakpoints have been established for *Salmonella* isolates from swine.

[†]Trimethoprim/sulfamethoxazole concentration on plate = 2/38 µg/mL.

TABLE 12. CLINICAL SYMPTOMS AND DIAGNOSES ASSOCIATED WITH PORCINE E. COLI INFECTIONS.

Clinical symptoms and/or diagnosis	Count	%
Diarrhea/enteric disease	97	67.8%
Pneumonia/respiratory disease	23	16.1%
Other diagnosis/unknown*	10	7.0%
Abscess/wound infection	6	4.2%
Sepsis/septicemia	5	3.5%
Abortion/placentitis	2	1.4%
TOTAL	143	

*Other/unknown diagnosis: skin infection (1), normal uterine flora (1), meningitis (1), nephritis (1), pleuritis (2), mulberry heart disease (1), nonspecific acute circulatory changes (1), and unknown diagnosis (2)

SWINE SALMONELLA

TABLE 13. MIC DISTRIBUTION FOR SALMONELLA ISOLATES RECOVERED FROM SWINE.

antibiotic class	MIC value (µg/mL) / Antibiotic	<=0.12	<=0.25	0.25	<=0.5	0.5	<=1	1	>1	<=2	2	>2	<=4	4	<=8	8	>8	16	>16	32	>32	64	>64	<=256	>256	Total Isolates[§]	% R*
3rd gen cephalosporin	**Ceftiofur**		0			5		47			14			1		1	14									82	
aminocyclitol	**Spectinomycin**														0			3		41		4	34			82	
aminoglycoside	**Gentamicin**						54				3			1		1		2	21							82	
aminoglycoside	**Neomycin**												62	0		1		1		2	16					82	
fluoroquinolone	**Danofloxacin**	65		0		2		7	8		0															82	
fluoroquinolone	**Enrofloxacin**	63		2		0		3			6	8														82	
folate pathway antagonist	**Sulphadimethoxine**																							20	62	82	
folate pathway antagonist	**Trimethoprim/sulfamethoxazole[†]**									62		20														82	
lincosamide	**Clindamycin**		0			0		0			0			0		0			82							82	
macrolide	**Gamithromycin**						0				0			6		22	3									31	
macrolide	**Tiamulin**						0				0			0		0		0		0	82					82	
macrolide	**Tildipirosin**						0				0			2		27	0		2							31	
macrolide	**Tilmicosin**									0			0			0		0	31	1		1	49			82	
macrolide	**Tulathromycin**						0				0			1	29	30		11		9	1	1	0			82	
macrolide	**Tylosin**				0			0			0			0		0		0		0	82					82	
penicillin	**Ampicillin**		0			4		19			6			1		0			52							82	
penicillin	**Penicillin**	0		0		0		0			0			0		16	66									82	
phenicol	**Florfenicol**		0			0		0			7			46		6	23									82	
tetracycline	**Chlortetracycline**				0			3			8			2		0	38									51	
tetracycline	**Oxytetracycline**				0			6			7			0		0	38									51	
tetracycline	**Tetracycline**				0			0			7			1		0	23									31	

[§] Total number of isolates for each antibiotic reflect a combination of the BOPO6F and B BOPO7F plates. Not all antibiotics in the table are present on both plates, leading to differences in total numbers of isolates.

* % R = percentage of resistant isolates. No antibiotic interpretive breakpoints have been established for *Salmonella* isolates from swine.

[†]Trimethoprim/sulfamethoxazole concentration on plate = 2/38 µg/mL.

TABLE 14. OVERALL PREVALENCE OF PORCINE SALMONELLA SEROTYPES.

Swine – Salmonella serotype, overall					
Salmonella Serotype	**count**	**%**	**Salmonella Serotype**	**count**	**%**
4,[5],12:i:-	28	34.1%	**Agbeni**	1	1.2%
Typhimurium	15	18.3%	**Anatum**	1	1.2%
Derby	10	12.2%	**Brandenburg**	1	1.2%
Infantis	4	4.9%	**Enteritidis**	1	1.2%
Choleraesuis var. Kunzendorf	3	3.7%	**Johannesburg**	1	1.2%
Agona	3	3.7%	**Mbandaka**	1	1.2%
Montevideo	3	3.7%	**Panama**	1	1.2%
Worthington	3	3.7%	**Saintpaul**	1	1.2%
Heidelberg	2	2.4%	**Uganda**	1	1.2%
Rissen	2	2.4%	**TOTAL**	82	

TABLE 15. DISTRIBUTION OF PORCINE SALMONELLA SEROTYPES BY CLINICAL SYMPTOMS/DIAGNOSES.

Diarrhea/enteric disease		
SEROTYPE	**COUNT**	**%**
4,5,12:i:-	20	40.0%
Typhimurium	8	16.0%
Derby	7	14.0%
Montevideo	3	6.0%
Agona	2	4.0%
Infantis	2	4.0%
Agbeni	1	2.0%
Anatum	1	2.0%
Johannesburg	1	2.0%
Mbandaka	1	2.0%
Panama	1	2.0%
Rissen	1	2.0%
Uganda	1	2.0%
Worthington	1	2.0%
TOTAL	50	

Other/unknown*		
SEROTYPE	**COUNT**	**%**
4,[5],12:l:-	3	18.8%
Choleraesuis var. Kunzendorf	3	18.8%
Typhimurium	3	18.8%
Agona	1	6.3%
Brandenburg	1	6.3%
Derby	1	6.3%
Heidelberg	1	6.3%
Infantis	1	6.3%
Rissen	1	6.3%
Worthington	1	6.3%
TOTAL	16	

Pneumonia/respiratory disease		
SEROTYPE	**COUNT**	**%**
4,[5],12:i:-	5	31.3%
Derby	2	12.5%
Typhimurium	2	12.5%
Infantis	1	6.3%
Saintpaul	1	6.3%
Worthington	1	6.3%
TOTAL	12	

Septicemia		
SEROTYPE	**COUNT**	**%**
Typhimurium	2	50.0%
Enteritidis	1	25.0%
Heidelberg	1	25.0%
TOTAL	4	

*Other/unknown = *Erysipelothrix rhusiopathiae* (1), fibrinous peritonitis (1), influenza (1), intravascular fibrin thrombosis (1), meningitis/hepatitis (1), meningoencephalitis (1), polyserositis (1), PRRS virus (5), rotavirus (1), streptococcal polyserositis (1), *Streptococcus suis* septicemia (1), acute illness/death (1).

APPENDIX C: Poultry MIC Distributions, Salmonella Serotypes and Clinical Symptoms

POULTRY - E. COLI- CHICKENS + TURKEYS COMBINED

TABLE 16. MIC DISTRIBUTION FOR E. COLI ISOLATES RECOVERED FROM CHICKENS AND TURKEYS, COMBINED.

antibiotic class	MIC value (µg/mL) / Antibiotic	<=0.12	0.12	<=0.25	0.25	<=0.5	0.5	<=1	1	<=2	2	>2	4	>4	<=8	8	>8	16	>16	20	>20	<=32	32	>32	64	>64	128	256	>256	Total Isolates	% R*
3rd gen cephalosporin	Ceftiofur			72			158		9		1		1	31																272	
aminocoumarin	Novobiocin					0			0		0		2	270																272	
aminocyclitol	Spectinomycin														32			160					11		8	61				272	
aminoglycoside	Gentamicin					108			72		3		0			4	85													272	
aminoglycoside	Neomycin									219	0		3			1		2					8	39						272	
aminoglycoside	Streptomycin														152			12					15		36		36	14	7	272	
fluoroquinolone	Enrofloxacin**	253			10		4		2		1	2																		272	1.1%
folate pathway antagonist	Sulphadimethoxine																					22	0		45		50	38	117	272	
folate pathway antagonist	Sulphathiazole																					133			22		4	2	111	272	
folate pathway antagonist	Trimethoprim/sulfamethoxazole†					245			2		1	24																		272	
lincosamide	Clindamycin					0			0		0		1	271																272	
macrolide	Erythromycin	1			1		0		0		0		0	270																272	
macrolide	Tylosin																			5	265		0	2						272	
penicillin	Amoxicillin			1			0		3		52		109			17	1	3	86											272	
penicillin	Penicillin	0	1		0		0		0		0		0			4	267													272	
phenicol	Florfenicol							0			97		157			13	5													272	
tetracycline	Oxytetracycline			0			1		68		64		5			0	134													272	
tetracycline	Tetracycline			0			3		84		48		2			2	133													272	

Poultry-specific interpretive criteria are indicated for selected antibiotics. Green shaded cells = sensitive, yellow shaded cells = intermediate and red shaded cells = resistant. Interpretive values are based on CLSI Vet08, 4th ed. (2018).

* % R = percentage of resistant isolates.

** Enrofloxacin is not approved for use in poultry in the U.S. as of 2017.

†Trimethoprim/sulfamethoxazole concentrations on plate = 0.5/9.5 µg/mL, 1/19 µg/mL, and 2/38 µg/mL.

TABLE 17. MIC DISTRIBUTION FOR E. COLI ISOLATES RECOVERED FROM CHICKENS.

antibiotic class	MIC value (µg/mL) / Antibiotic	<=0.12	0.1	<=0.25	0.25	<=0.5	0.5	<=1	1	<=2	2	>2	4	>4	<=8	8	>8	16	>16	20	>20	<=32	32	>32	64	>64	128	256	>256	Total Isolates	% R*
3rd gen cephalosporin	**Ceftiofur**			54			118		3		0		1	29																205	
aminocoumarin	**Novobiocin**					0			0		0		2	203																205	
aminocyclitol	**Spectinomycin**														20			121					6		7	51				205	
aminoglycoside	**Gentamicin**					85			44		2		0			4	70													205	
aminoglycoside	**Neomycin**									176	0		3			0		1					6	19						205	
aminoglycoside	**Streptomycin**														118			11					13		28		20	12	3	205	
fluoroquinolone	**Enrofloxacin****	190			9		3		0		1	2																		205	1.5%
folate pathway antagonist	**Sulphadimethoxine**																					19	0		33		42	30	81	205	
folate pathway antagonist	**Sulphathiazole**																					107			18		4	2	74	205	
folate pathway antagonist	**Trimethoprim/sulfamethoxazole†**					186			2		0	17																		205	
lincosamide	**Clindamycin**					0			0		0		1	204																205	
macrolide	**Erythromycin**	1			1		0		0		0		0	203																205	
macrolide	**Tylosin**																			5	199		0	1						205	
penicillin	**Amoxicillin**			1			0		3		46		77			14	1	3	60											205	
penicillin	**Penicillin**	0	1		0		0		0		0		0			4	200													205	
phenicol	**Florfenicol**							0			70		120			11	4													205	
tetracycline	**Oxytetracycline**			0			1		65		41		2			0	96													205	
tetracycline	**Tetracycline**			0			3		70		33		1			2	96													205	

Poultry-specific interpretive criteria are indicated for selected antibiotics. Green shaded cells = sensitive, yellow shaded cells = intermediate and red shaded cells = resistant. Interpretive values are based on CLSI Vet08, 4th ed. (2018).

* % R = percentage of resistant isolates.

** Enrofloxacin is not approved for use in poultry in the U.S. as of 2017.

†Trimethoprim/sulfamethoxazole concentrations on plate = 0.5/9.5 µg/mL, 1/19 µg/mL, and 2/38 µg/mL.

POULTRY – *E. COLI* – TURKEYS

TABLE 18. MIC DISTRIBUTION FOR E. COLI ISOLATES RECOVERED FROM TURKEYS.

antibiotic class	Antibiotic \ MIC value (µg/mL)	<=0.12	0.1	<=0.25	0.25	<=0.5	0.5	<=1	1	<=2	2	>2	4	>4	<=8	8	>8	16	>16	20	>20	<=32	32	>32	64	>64	128	256	>256	Total Isolates	% R*
3rd gen cephalosporin	**Ceftiofur**			18			40		6		1		0	2																67	
aminocoumarin	**Novobiocin**					0			0		0		0	67																67	
aminocyclitol	**Spectinomycin**														12			39					5		1	10				67	
aminoglycoside	**Gentamicin**					23			28		1		0			0	15													67	
aminoglycoside	**Neomycin**									43	0		0			1		1					2	20						67	
aminoglycoside	**Streptomycin**														34			1					2		8		16	2	4	67	
fluoroquinolone	**Enrofloxacin****	63			1		1		2		0	0																		67	0%
folate pathway antagonist	**Sulfadimethoxine**																					3	0		12		8	8	36	67	
folate pathway antagonist	**Sulfathiazole**																					26			4		0	0	37	67	
folate pathway antagonist	**Trimethoprim/sulfamethoxazole†**					59			0		1	7																		67	
lincosamide	**Clindamycin**					0			0		0		0	67																67	
macrolide	**Erythromycin**	0			0		0		0		0		0	67																67	
macrolide	**Tylosin**																			0	66		0	1						67	
penicillin	**Amoxicillin**			0			0		0		6		32			3	0	0	26											67	
penicillin	**Penicillin**	0	0		0		0		0		0		0			0	67													67	
phenicol	**Florfenicol**							0			27		37			2	1													67	
tetracycline	**Oxytetracycline**			0			0		3		23		3			0	38													67	
tetracycline	**Tetracycline**			0			0		14		15		1			0	37													67	

Poultry-specific interpretive criteria are indicated for selected antibiotics. Green shaded cells = sensitive, yellow shaded cells = intermediate and red shaded cells = resistant. Interpretive values are from CLSI Vet08, 4th ed. (2018).

* % R = percentage of resistant isolates.

** Enrofloxacin is not approved for use in poultry in the U.S. as of 2017.

†Trimethoprim/sulfamethoxazole concentrations on plate = 0.5/9.5 µg/mL, 1/19 µg/mL, and 2/38 µg/mL.

TABLE 19. CLINICAL SYMPTOMS AND DIAGNOSES ASSOCIATED WITH POULTRY E. COLI INFECTIONS.

CHICKENS*	COUNT	%
E. COLI INFECTION/SEPTICEMIA/COLIBACILLOSIS	65	31.7%
REPRODUCTIVE TRACT/YOLK SAC INFECTION *Coelomitis (12), egg yolk peritonitis (7), omphalitis (25), salpingitis (10)*	54	26.3%
OTHER/UNKNOWN**	42	20.5%
MIXED/SECONDARY INFECTION	14	6.8%
PNEUMONIA/BRONCHITIS/RESPIRATORY INFECTION	13	6.3%
AIRSACCULITIS	8	3.9%
ABSCESS/WOUND INFECTION	5	2.4%
ENTERITIS	4	2.0%
TOTAL	**205**	

TURKEYS	COUNT	%
E. COLI INFECTION/SEPTICEMIA/COLIBACILLOSIS	21	31.3%
OTHER/UNKNOWN†	17	25.4%
PNEUMONIA	15	22.4%
MIXED/SECONDARY INFECTION	6	9.0%
AIRSACCULITIS	4	6.0%
ENTERITIS	3	4.5%
YOLK SAC INFECTION	1	1.5%
TOTAL	**67**	

*includes one duck

** Other/unknown (chickens) – arthritis (1), bacterial bumblefoot (1), coccidiosis (1), encephalitis (2), endocarditis (5), gallibacterium (1), hepatitis (7), low production (1), osteomyelitis (1), Pasteurellosis (1), pericarditis (1), peritonitis (4), severe necrotizing bacterial stomatitis (1), severe parenteral vaccine reaction (1), visceral gout (1), unknown/no dx provided (13)

† Other/unknown (turkeys) – coccidiosis (1), erysipelas (1), pericarditis/peritonitis (1), hepatopathy (1), Newcastle Disease virus (3), *Ornithobacterium rhinotracheale* (6), reoviral arthritis (2), encephalitis (1), systemic *Staphylococcus aureus* (1)

POULTRY – *SALMONELLA* – CHICKENS AND TURKEYS

TABLE 20. MIC DISTRIBUTION OF SALMONELLA ISOLATES FROM CHICKENS AND TURKEYS, COMBINED.

antibiotic class	Antibiotic \ MIC value (µg/mL)	<=0.12	0.12	<=0.25	0.25	<=0.5	0.5	<=1	1	<=2	2	>2	4	>4	<=8	8	>8	16	>16	>20	<=32	32	>32	64	>64	128	256	>256	Total Isolates	% R*
3rd gen cephalosporin	**Ceftiofur**			1			5		43		9		1	4															63	
aminocoumarin	**Novobiocin**					0			0		0		0	63															63	
aminocyclitol	**Spectinomycin**														1			12				37		8	5				63	
aminoglycoside	**Gentamicin**					43			10		1		1			2	6												63	
aminoglycoside	**Neomycin**									61			2			0		0				0	0						63	
aminoglycoside	**Streptomycin**														33			5				11		6		7	1		63	
fluoroquinolone	**Enrofloxacin****	60			1		1		0		1	0																	63	1.6%
folate pathway antagonist	**Sulphadimethoxine**																				0			6		9	10	38	63	
folate pathway antagonist	**Sulphathiazole**																				26			24		4	1	8	63	
folate pathway antagonist	**Trimethoprim/sulfamethoxazole†**					63			0		0	0																	63	
lincosamide	**Clindamycin**					0			0		0		0	63															63	
macrolide	**Erythromycin**	0	0		0		0		0		0		0	63															63	
macrolide	**Tylosin**																			62		0	1						63	
penicillin	**Amoxicillin**			0			0		48		7		1			0			7										63	
penicillin	**Penicillin**	0			0		0		0		0		3			29	31												63	
phenicol	**Florfenicol**							1			22		37			2	1												63	
tetracycline	**Oxytetracycline**			0			1		30		21		0			0	11												63	
tetracycline	**Tetracycline**			0			4		28		20		0			0	11												63	

Poultry-specific interpretive criteria are indicated for selected antibiotics. Green shaded cells = sensitive, yellow shaded cells = intermediate and red shaded cells = resistant. Interpretive values are from CLSI Vet08, 4th ed. (2018).

* % R = percentage of resistant isolates.

** Enrofloxacin is not approved for use in poultry in the U.S. as of 2017.

†Trimethoprim/sulfamethoxazole concentrations on plate = 0.5/9.5 µg/mL, 1/19 µg/mL, and 2/38 µg/mL.

TABLE 21. MIC DISTRIBUTION OF SALMONELLA ISOLATES FROM CHICKENS.

antibiotic class	Antibiotic \ MIC value (µg/mL)	<=0.12	<=0.25	0.25	<=0.5	0.5	<=1	1	<=2	2	>2	4	>4	<=8	8	>8	16	>16	>20	<=32	32	>32	64	>64	128	256	>256	Total Isolates	%R*
3rd gen cephalosporin	**Ceftiofur**		1			4		34		9		1	3															52	
aminocoumarin	**Novobiocin**				0			0		0		0	52															52	
aminocyclitol	**Spectinomycin**													1			11				33		4	3				52	
aminoglycoside	**Gentamicin**				39			7		1		1			2	2												52	
aminoglycoside	**Neomycin**								50			2			0		0				0	0						52	
aminoglycoside	**Streptomycin**													30			3				8		5		6	0		52	
fluoroquinolone	**Enrofloxacin****	49		1		1		0		1	0																	52	1.9%
folate pathway antagonist	**Sulphadimethoxine**																			0			6		9	6	31	52	
folate pathway antagonist	**Sulphathiazole**																			20			20		4	1	7	52	
folate pathway antagonist	**Trimethoprim/sulfamethoxazole†**				52			0		0	0																	52	
lincosamide	**Clindamycin**				0			0		0		0	52															52	
macrolide	**Erythromycin**	0		0		0		0		0		0	52															52	
macrolide	**Tylosin**																		51		0	1						52	
penicillin	**Amoxicillin**		0			0		41		6		1			0			4										52	

penicillin	**Penicillin**	0		0		0		0		0		3			27	22													52	
phenicol	**Florfenicol**						1			17		31			2	1													52	
tetracycline	**Oxytetracycline**		0			1		26		16		0			0	9													52	
tetracycline	**Tetracycline**		0			4		23		16		0			0	9													52	

Poultry-specific interpretive criteria are indicated for selected antibiotics. Green shaded cells = sensitive, yellow shaded cells = intermediate and red shaded cells = resistant. Interpretive values are from CLSI Vet08, 4th ed. (2018).

* % R = percentage of resistant isolates.

** Enrofloxacin is not approved for use in poultry in the U.S. as of 2017.

†Trimethoprim/sulfamethoxazole concentrations on plate = 0.5/9.5 µg/mL, 1/19 µg/mL, and 2/38 µg/mL.

TABLE 22. DISTRIBUTION OF SALMONELLA SEROTYPES AND CLINICAL DIAGNOSIS OR REASON FOR SUBMISSION IN CHICKENS.

SEROTYPE	COUNT	%	DIAGNOSIS or REASON FOR SUBMISSION*
Enteriditis	18	34.6%	coelomitis (2), omphalitis (1), salmonellosis (1), coccidiosis (1), Salmonella genotyping (13)
Typhimurium	12	23.1%	air sacculitis (1), arthritis (1), colibacillosis(1), meningoencephalitis (1), hepatitis (1), NPIP testing (1), opthalmitis (1), pericardidtis/epicarditis (1), salmonellosis (1), Salmonella genotyping (1), unknown (2)
Kentucky	7	13.5%	coccidiosis (1), osteomyelitis (1), serositis (1), Salmonella genotyping (4)
Infantis	4	7.7%	bacterial septicemia (1), salmonellosis (1), Salmonella genotyping (2)
(no serotype given)	2	3.8%	salmonellosis (2)
Braenderup	2	3.8%	Salmonella genotyping
Rough O:e,h:e,n,z15	1	1.9%	NPIP testing
Oranienburg	1	1.9%	bacterial infection
Heidelberg	1	1.9%	salmonellosis
Hadar	1	1.9%	Salmonella genotyping
Mbdanka	1	1.9%	Salmonella genotyping
Montevideo	1	1.9%	Salmonella genotyping
Muenchen	1	1.9%	Salmonella genotyping
TOTAL	52		

* Participating laboratories were asked to provide the reason for submission if a clinical diagnosis was not available.

TABLE 23. MIC DISTRIBUTION OF SALMONELLA ISOLATES FROM TURKEYS.

antibiotic class	MIC value (µg/mL) / Antibiotic	<=0.12	<=0.25	0.25	<=0.5	0.5	<=1	1	<=2	2	>2	4	>4	<=8	8	>8	16	>16	>20	<=32	32	>32	64	>64	128	256	>256	Total Isolates	%R*
3rd gen cephalosporin	**Ceftiofur**		0			1		9		0		0	1															11	
aminocoumarin	**Novobiocin**				0			0		0		0	11															11	
aminocyclitol	**Spectinomycin**													0			1				4		4	2				11	
aminoglycoside	**Gentamicin**				4			3		0		0			0	4												11	
aminoglycoside	**Neomycin**								11			0			0		0				0	0						11	
aminoglycoside	**Streptomycin**													3			2				3		1		1	1		11	
fluoroquinolone	**Enrofloxacin****	11		0		0		0		0	0																	11	0.0%
folate pathway antagonist	**Sulphadimethoxine**																			0			0		0	4	7	11	
folate pathway antagonist	**Sulphathiazole**																			6			4		0	0	1	11	
folate pathway antagonist	**Trimethoprim/sulfamethoxazole†**				11			0		0	0																	11	
lincosamide	**Clindamycin**				0			0		0		0	11															11	
macrolide	**Erythromycin**	0		0		0		0		0		0	11															11	
macrolide	**Tylosin**																		11		0	0						11	
penicillin	**Amoxicillin**		0			0		7		1		0			0			3										11	

penicillin	**Penicillin**	**0**		**0**		**0**		**0**		**0**		**0**			**2**	**9**											**11**	
phenicol	**Florfenicol**						**0**			**5**		**6**			**0**	**0**											**11**	
tetracycline	**Oxytetracycline**		**0**			**0**		**4**		**5**		**0**			**0**	**2**											**11**	
tetracycline	**Tetracycline**		**0**			**0**		**5**		**4**		**0**			**0**	**2**											**11**	

Poultry-specific interpretive criteria are indicated for selected antibiotics. Green shaded cells = sensitive, yellow shaded cells = intermediate and red shaded cells = resistant. Interpretive values are from CLSI Vet08, 4th ed. (2018).

* % R = percentage of resistant isolates.

** Enrofloxacin is not approved for use in poultry in the U.S. as of 2017.

†Trimethoprim/sulfamethoxazole concentrations on plate = 0.5/9.5 µg/mL, 1/19 µg/mL, and 2/38 µg/mL.

TABLE 24. DISTRIBUTION OF SALMONELLA SEROTYPES AND CLINICAL DIAGNOSIS OR REASON FOR SUBMISSION IN TURKEYS.

SEROTYPE	COUNT	%	DIANGOSIS
Typhimurium	3	27.3%	bacterial infection (1), enteritis (1), omphalitis/septicemia (1)
Bredeney	2	18.2%	Bacterial infection (1), salmonellosis (1)
Uganda	2	18.2%	dehydration/"flushing" in poults (1), enteritis (1)
Infantis	1	9.1%	Septicemia
Mbandaka	1	9.1%	Enteritis
Senftenberg	1	9.1%	Bacterial infection
TOTAL	11		

APPENDIX D: Equine MIC Distributions, Salmonella Serotypes and Clinical Symptoms

HORSES - *E. COLI*

TABLE 25. MIC DISTRIBUTION FOR E. COLI ISOLATES RECOVERED FROM HORSES.

antibiotic class	MIC value (µg/mL) / Antibiotic	<=0.06	0.12	<=0.25	0.25	<=0.5	0.5	<=1	1	>1	<=2	2	>2	<=4	4	>4	<=8	8	>8	16	>16	32	>32	64	>64	Total Isolates	%R*
1st gen cephalosporin	Cefazolin							2						149	0			1		3	34					189	
3rd gen cephalosporin	Ceftazidime							167				7			1			1		5		5		2	1	189	
3rd gen cephalosporin	Ceftiofur			58			93		3			3			1	31										189	
aminoglycoside	Amikacin**													183	0			5		0		0	1			189	0.5%
aminoglycoside	Gentamicin							150				6			1			0	32							189	16.9%
βlactam/β-lactamase inhibitor	Ticarcillin/Clavulanic acid																149			14		14		6	6	189	
fluoroquinolone	Enrofloxacin§			170			2		2			0	15													189	10.1%
folate pathway inhibitor	Trimethoprim/sulfamethoxazole†					109			1			2	0		1	76										189	
macrolide	Azithromycin			0			0		7			60			97	25										189	
macrolide	Clarithromycin							0				1			0			0	188							189	
macrolide	Erythromycin	0	0		0		0		0			0			0	1		0	188							189	
penem	Imipenem							189				0			0			0	0							189	
penicillin	Ampicillin					0			10	1		64			58			5		0		2	49			189	
penicillin	Oxacillin			0			0		1			0			0	188										189	
penicillin	Penicillin	0	0		0		0		0			0			1			1	187							189	
penicillin/carboxypenicillin	Ticarcillin																134			4		0		2	49	189	
phenicol	Chloramphenicol										1			79				80		1	1	1	26			189	
rifamycin	Rifampin							0				1	1		82	105										189	
tetracycline	Doxycycline§										130				7			9		11	32					189	31.2%
tetracycline	Tetracycline										136				1			1	51							189	

Equine-specific interpretive criteria are indicated for selected antibiotics. Green shaded cells = sensitive, yellow shaded cells = intermediate and red shaded cells = resistant. Interpretive values are from CLSI Vet08, 4th ed. (2018).

* % R = percentage of resistant isolates.

*Amikacin breakpoints for adult animals are shown. Foal breakpoints are: S ≤2, I = 4, R ≥8.

§Enrofloxacin and doxycycline dilutions on the antibiotic sensitivity plate are above the breakpoint values for sensitive and intermediate. Thus interpretation of MIC data was restricted to only resistant values. Doxycycline breakpoints for horses are: S ≤0.12; I = 0.25; R ≥0.5, and enrofloxacin breakpoints for horses are: S ≤0.12; I = 0.25; R ≥0.5.

†Trimethoprim/sulfamethoxazole concentrations on plate = 0.5/9.5 µg/mL, 1/19 µg/mL, 2/38, and 4/76 µg/mL.

TABLE 26. CLINICAL SYMPTOMS AND DIAGNOSES ASSOCIATED WITH EQUINE E. COLI INFECTIONS.

Clinical symptom/diagnosis	Count	%
REPRODUCTIVE TRACT INFECTIONS	92	48.7%
SKIN INFECTION/WOUNDS	26	13.8%
UNKNOWN/NO DIAGNOSIS	22	11.6%
DIARRHEA/ENTERIC INFECTION	19	10.1%
RESPIRATORY TRACT INFECTION/PNEUMONIA	8	4.2%
PERITONITIS	6	3.2%
SEPSIS/SEPTICEMIA	6	3.2%
ARTHRITIS/JOINT INFECTIONS	4	2.1%
OTHER	4	2.1%
URINARY TRACT INFECTION	2	1.1%
TOTAL	189	1

HORSES – *SALMONELLA* SPP.

TABLE 27. MIC DISTRIBUTION FOR SALMONELLA SPP. ISOLATES RECOVERED FROM HORSES.

antibiotic class	Antibiotic \ MIC value (µg/mL)	<=0.06	0.12	<=0.25	0.25	<=0.5	0.5	<=1	1	<=2	2	>2	<=4	4	>4	<=8	8	>8	16	>16	32	>32	64	>64	Total Isolates	%R*
1st gen cephalosporin	Cefazolin							0					61	0			0		0	11					72	
3rd gen cephalosporin	Ceftazidime							61			1			0			2		1		0		4	3	72	
3rd gen cephalosporin	Ceftiofur			0			6		52		4			1	9										72	
aminoglycoside	Amikacin												67	0			0		2		2	1			72	6.9%
aminoglycoside	Gentamicin							60			1			1			2	8							72	13.9%
β lactam/β-lactamase inhibitor combos	Ticarcillin/Clavulanic acid															55	2		3		3		5	4	72	
fluoroquinolone	Enrofloxacin			69			1		1		0	1													72	
folate pathway inhibitor	Trimethoprim/sulfamethoxazole†					62			0		0			0	10										72	
macrolide	Azithromycin			0			0		0		9			50	13										72	
macrolide	Clarithromycin							0			0			0			0	72							72	
macrolide	Erythromycin	0	0		0		0		0		0			0			0	72							72	
penem	Imipenem							71			1			0			0	0							72	
penicillin	Ampicillin					1			51		3			1			0		0		0	16			72	
penicillin	Oxacillin			0			0		0		0			0	72										72	
penicillin	Penicillin	0	0		0		0		0		0			1			42	29							72	
penicillin/carboxypenicillin	Ticarcillin															56			0		1		1	14	72	
phenicol	Chloramphenicol												29				28		2		0	13			72	
rifamycin	Rifampin							0			0			1	71										72	
tetracycline	Doxycycline									51				6			4		2	9					72	
tetracycline	Tetracycline									58				1			0	13							72	

Equine-specific interpretive criteria are indicated for selected antibiotics. Green shaded cells = sensitive, yellow shaded cells = intermediate and red shaded cells = resistant. Interpretive values are from CLSI Vet08, 4th ed. (2018).

* % R = percentage of resistant isolates.

†Trimethoprim/sulfamethoxazole concentrations on plate = 0.5/9.5 µg/mL, 1/19 µg/mL, 2/38, and 4/76 µg/mL.

TABLE 28. DISTRIBUTION OF SALMONELLA SEROTYPES AND CLINICAL SYMPTOMS/DIAGNOSIS IN HORSES.

DIARRHEA/ENTERIC INFECTIONS					
SEROTYPE	**COUNT**	**%**	**SEROTYPE**	**COUNT**	**%**
Typhimurium	11	17.2%	4,5,12:i:-	1	1.6%
Newport	9	14.1%	Albany	1	1.6%
4,[5],12:i:-	3	4.7%	Carrau	1	1.6%
Agona	3	4.7%	Dublin	1	1.6%
Anatum	3	4.7%	Infantis	1	1.6%
Javiana	3	4.7%	Mbandaka	1	1.6%
Montevideo	3	4.7%	Miami	1	1.6%
Muenchen	3	4.7%	Mississippi	1	1.6%
Thompson	3	4.7%	Norwich	1	1.6%
Enteritidis	2	3.1%	Oranienburg	1	1.6%
Hartford	2	3.1%	rough O:eh:1,5	1	1.6%
Litchfield	2	3.1%	Sandiego	1	1.6%
Meleagridis	2	3.1%	Senftenberg	1	1.6%
4,(5),12:b:-	1	1.6%	Taksony	1	1.6%
			TOTAL	64	

OTHER/UNDETERMINED*		
SEROTYPE	**COUNT**	**%**
Typhimurium	2	50.0%
III 53:z4,z24:-	1	25.0%
Mbandaka	1	25.0%
TOTAL	4	

ARTHRITIS		
SEROTYPE	**COUNT**	**%**
Typhimurium	2	100.0%
TOTAL	2	

NEPHRITIS, HEPATITIS, PERITONITIS		
SEROTYPE	**COUNT**	**%**
Typhimurium	1	100.0%
TOTAL	1	

***** Other diagnoses: ulcerative gastritis (1), pulmonary arteritis (1), abscess (1), transmural hemorrhage/necrosis (1)

APPENDIX E: Dogs MIC Distributions, Salmonella Serotypes and Clinical Symptoms

DOGS – E. COLI - URINARY TRACT INFECTIONS

TABLE 29. MIC DISTRIBUTION FOR E. COLI UTI ISOLATES RECOVERED FROM DOGS.

Antibiotic class	Antibiotic \ MIC value (µg/mL)	<=0.12	<=0.25	0.25	<=0.5	0.5	<=1	1	>1	<=2	2	>2	<=4	4	>4	<=8	8	>8	16	>16	32	>32	64	>64	Total Isolates	%R*
1st gen cephalosporin	Cefazolin**						55				141			23			11		5		1	57			293	19.8%
1st gen cephalosporin	Cephalexin**				0			0			2			56			152		19	64					293	21.8%
3rd gen cephalosporin	Cefovecin**		14	1		95		95			23			6			2	57							293	20.1%
3rd gen cephalosporin	Cefpodoxime§						225				4			5			1	58							293	20.1%
3rd gen cephalosporin	Ceftazidime§												249	0			7		16	21					293	
aminoglycoside	Amikacin						1						275				15		2		0	0			293	0.7%
aminoglycoside	Gentamicin		12	1		146		109			8			3			0	14							293	4.8%
β lactam/β-lactamase inhibitor combo	Amoxicillin/Clavulanic acid**†‡		0			0		3			26			141			61	62							293	
β lactam/β-lactamase inhibitor combo	Piperacillin/tazobactam															281			5		5		1	1	293	2.4%
carbapenem	Imipenem						292	0			0			1			0	0							293	
fluoroquinolone	Enrofloxacin	227		8		9		3			0			0	46										293	15.7%
fluoroquinolone	Marbofloxacin	226		7		10		4			0			1	45										293	15.7%
fluoroquinolone	Orbifloxacin						236				8			3			0	46							293	15.7%
fluoroquinolone	Pradofloxacin		243			4		0			3	43													293	15.7%
folate pathway antagonist	Trimethoprim/sulfamethoxazole°				236			6			3			4	44										293	
penicillin	Ampicillin**†		0			3		5			72			96			21	96							293	
phenicol	Chloramphenicol									1				51			172		41		3	25			293	
tetracycline	Doxycycline		1			2		65			131			36			10	48							293	
tetracycline	Tetracycline												234				2		2	55					293	

Canine-specific interpretive criteria are indicated for selected antibiotics. Green shaded cells = sensitive, yellow shaded cells = intermediate and red shaded cells = resistant. Interpretive values are based on CLSI Vet08, 4th ed. (2018).

*Percentage of resistant isolates.

**Antibiotics with separate breakpoints for canine *E. coli* urinary tract infections (UTIs).

§Extended spectrum beta-lacatmase (ESBL) testing is indicated for isolates with MIC ≥ 8 mg/mL for cefpodoxime, or >2 mg/mL for ceftazidime.

†Breakpoints for intermediate and resistant values for amoxicillin/clavulanic acid and ampicillin have not been established for UTIs in dogs.

‡ Amoxicillin/clavulanic acid concentrations on plate are 0.25/0.12, 0.5/0.25, 1/0.5, 2/1, 4/2 and 8/4 µg/mL.

Trimethoprim/sulfamethoxazole concentrations on plate are 0.12/2.38, 0.25/4.75, 0.5/9.5 µg/mL, 1/19 µg/mL, 2/38, and 4/76 µg/mL.

TABLE 30. ANTIBIOTIC RESISTANCE ANALYSIS FOR CANINE E. COLI UTI ISOLATES.

		Number of resistant isolates by antibiotic class and individual antibiotic										
No. of antibiotic resistant phenotypes per isolate	**No. isolates (% total)**	**AMINOGLYCOSIDE**		**CEPHALOSPORIN**				**FLUOROQUINOLONE**				**B LACTAM COMBO**
		Amikacin No. resistant	**Gentamicin No. resistant**	**Cefazolin No. resistant**	**Cefovecin No. resistant**	**Cefpodoxime No. resistant**	**Cephalexin No. resistant**	**Enrofloxacin No. resistant**	**Marbofloxacin No. resistant**	**Orbifloxacin No. resistant**	**Pradofloxacin No. resistant**	**Piperacillin/tazobactam, No. resistant**
10	1 (0.3%)	1	1	1	1	1	1	1	1	1	1	0
9	13 (4.4%)	0	8	13	13	13	13	13	13	13	13	5
8	22 (7.5%)	0 (3 intermediate susceptibility)	0 (1 intermediate susceptibility)	22	22	22	22	22	22	22	22	0 (3 intermediate susceptibility)
7	0 (0%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	2 (0.7%)	0 (1 intermediate susceptibility)	1	1	2	1 (1 intermediate susceptibility)	2	1 (1 intermediate susceptibility)	1	1 (1 intermediate susceptibility)	1 (1 intermediate susceptibility)	1 (1 intermediate susceptibility
5	2 (0.7%)	0	1	2	2	2	2	0	0	0 (1 intermediate susceptibility)	0	1
4	27 (9.2%)	0 (1 intermediate susceptibility)	0	18	18	18	18	9	9	9 (3 intermediate susceptibility)	9 (1 intermediate susceptibility)	0
3	1 (0.3%)	0	0	1	0 (1 intermediate susceptibility)	1	1	0	0	0	0	0
2	2 (0.7%)	0	0	0	1	1 (1 intermediate susceptibility)	2	0	0	0 (5 intermediate susceptibility)	0	0
1	7 (2.4%)	1	3 (1 intermediate susceptibility)	0	0	0 (3 intermediate susceptibility)	3	0	0	0 (1 intermediate susceptibility)	0	0
0	216 (73.7%)	0 (6 intermediate susceptibility)	0 (1 intermediate susceptibility)	0	0 (4 intermediate susceptibility)	0	0	0 (2 intermediate susceptibility)	0	0	(2 intermediate susceptibility)	0 (1 intermediate susceptibility)
TOTAL	293											

DOGS – *E. COLI* - NON-UTI

TABLE 31. MIC DISTRIBUTION FOR E. COLI NON-UTI ISOLATES RECOVERED FROM DOGS.

Antibiotic class	MIC value (µg/mL) / Antibiotic	<=0.12	<=0.25	0.25	<=0.5	0.5	<=1	1	>1	<=2	2	>2	<=4	4	>4	<=8	8	>8	16	>16	32	>32	64	>64	Total Isolates	%R*
1st gen cephalosporin	Cefazolin						34				70			13			6		0		0	43			166	29.5%
1st gen cephalosporin	Cephalexin				0			0			0			45			72		5	44					166	72.9%
3rd gen cephalosporin	Cefovecin		10			64		46			3			1			0	42							166	
3rd gen cephalosporin	Cefpodoxime**						121				0			2			1	42							166	25.9%
3rd gen cephalosporin	Ceftazidime**												133	0			7		15	11					166	
aminoglycoside	Amikacin						1						159				6		0		0	0			166	0.0%
aminoglycoside	Gentamicin		5	0		83		49			6			2			2	19							166	12.7%
β lactam/β-lactamase inhibitor combo	Amoxicillin/ Clavulanic acid†		0			0		2			13			85			27	39							166	100.0%
β lactam/β-lactamase inhibitor combo	Piperacillin/tazobactam															161			3		1		0	1	166	1.2%
carbapenem	Imipenem						166	0			0			0			0	0							166	
fluoroquinolone	Enrofloxacin	124		8		3		3			1			1	26										166	16.3%
fluoroquinolone	Marbofloxacin	124		6		9		0			0			0	27										166	16.3%
fluoroquinolone	Orbifloxacin						133				4			1			1	27							166	16.9%
fluoroquinolone	Pradofloxacin		136			3		0			2	25													166	16.3%
folate pathway antagonist	Trimethoprim/sulfamethoxazole§				135			2			1			1	27										166	
penicillin	Ampicillin		0			1		2			48			47			1	67							166	99.4%
phenicol	Chloramphenicol									6				46			81		13		3	17			166	
tetracycline	Doxycycline		0			7		53			55			12			10	29							166	
tetracycline	Tetracycline												123				2		0	41					166	

Canine-specific interpretive criteria are indicated for selected antibiotics. Green shaded cells = sensitive, yellow shaded cells = intermediate and red shaded cells = resistant. Interpretive values are based on CLSI Vet08, 4th ed. (2018).

*Percentage of resistant isolates.

**Extended spectrum beta-lactamase (ESBL) testing is indicated for isolates with MIC ≥ 8 mg/mL for cefpodoxime, or >2 mg/mL for ceftazidime.

†Amoxicillin/clavulanic acid concentrations on plate are 0.25/0.12, 0.5/0.25, 1/0.5, 2/1, 4/2 and 8/4 µg/mL.

§Trimethoprim/sulfamethoxazole concentrations on plate are 0.12/2.38, 0.25/4.75, 0.5/9.5 µg/mL, 1/19, 2/38, and 4/76 µg/mL.

TABLE 32. ANTIBIOTIC RESISTANCE ANALYSIS FOR CANINE E. COLI NON-UTI ISOLATES.

		Number of resistant isolates by antibiotic class and individual antibiotic											
		AMINOGLYCOSIDE		CEPHALOSPORIN			FLUOROQUINOLONE				B LACTAM COMBO		PENICILLIN
No. of antibiotic resistant phenotypes per isolate	No. isolates (% total)	Amikacin No. resistant	Gentamicin No. resistant	Cefazolin No. resistant	Cefpodoxime No. resistant	Cephalexin No. resistant	Enrofloxacin No. resistant	Marbofloxacin No. resistant	Orbifloxacin No. resistant	Pradofloxacin No. resistant	Piperacillin/ tazobactam No. resistant	Amoxacillin/clavulanic acid No. resistant	Ampicillin No. resistant
10	13 (7.8%)	0	13	13	13	13	13	13	13	13	2 (2 intermediate susceptibility)	13	13
9	12 (7.2%)	0	1	12	12	14	14	14	14	14	0	12	12
8	0 (0%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	0 (0%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	5 (3.0%)	0	3	3	3	3 (2 intermediate susceptibility	2	2 (1 intermediate susceptibility)	0 (1 intermediate susceptibility)	2 (1 intermediate susceptibility)	0	5	5
5	17 (10.2%)	0	1 (1 intermediate susceptibility)	17	16	17	0 (2 intermediate susceptibility)	0	0 (2 intermediate susceptibility)	0	0	17	17
4	9 (5.4%)	0	4	4 (2 intermediate susceptibility)	0	9	0 (1 intermediate susceptibility)	0	1	0 (1 intermediate susceptibility)	0	9	9
3	68 (41.0%)	0	1	0 (10 intermediate susceptibility)	0 (2 intermediate susceptibility)	67 (1 intermediate susceptibility)	0	0	0	0	0	68	68
2	41 (24.7%)	0	0	0	0	0 (41 intermediate susceptibility)	0	0	0 (2 intermediate susceptibility)	0 (1 intermediate susceptibility)	0	41	41
1	1 (0.6%)	0	0	0	0	0 (1 intermediate susceptibility)	0	0	0	0	0	1	0
0	0 (0%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TOTAL	166	0	23	49	44	113	29	29	28	29	2	166	165

TABLE 33. CLINICAL SYMPTOMS AND DIAGNOSES ASSOCIATED WITH CANINE E. COLI INFECTIONS.

Clinical symptom/diagnosis	COUNT	%
ABSCESS/SKIN/WOUND INFECTION	51	30.7%
OTITIS/EAR INFECTION	28	16.9%
DIARRHEA/ENTERIC INFECTIONS	17	10.2%
RESPIRATORY INFECTION/PNEUMONIA	16	9.6%
REPRODUCTIVE TRACT INFECTIONS	16	9.6%
NEPHRITIS, HEPATITIS, PERITONITIS	9	5.4%
SEPSIS/SEPTICEMIA	8	4.8%
UNDETERMINED	6	3.6%
CHOLECYSTITIS	5	3.0%
PROSTATITIS	5	3.0%
OTHER*	3	1.8%
MASTITIS	2	1.2%
TOTAL	166	

*Other diagnoses: neoplasia (1), proliferative bone lesion/delayed healing (1), canine herpesvirus (1).

Dogs – Salmonella

TABLE 34. MIC DISTRIBUTION FOR SALMONELLA ISOLATES RECOVERED FROM DOGS.

Antibiotic class	Antibiotic \ MIC value (µg/mL)	<=0.12	<=0.25	0.25	<=0.5	0.5	<=1	1	>1	<=2	2	>2	<=4	4	>4	<=8	8	>8	16	>16	32	>32	64	>64	Total Isolates	%R*
1st gen cephalosporin	Cefazolin						0				11			0			1		0		0	2			14	
1st gen cephalosporin	Cephalexin				0			0			0			10			2		0	2					14	
3rd gen cephalosporin	Cefovecin		1			6		4			1			0			0	2							14	
3rd gen cephalosporin	Cefpodoxime						12				0			0			0	2							14	
3rd gen cephalosporin	Ceftazidime												12				0		1	1					14	
aminoglycoside	Amikacin												14				0		0		0	0			14	
aminoglycoside	Gentamicin		5		1	7		1			0			0			0	0							14	0.0%
β lactam/β-lactamase inhibitor combo	Amoxicillin/ Clavulanic acid[T]		0			0		12			0			0			0	2							14	
β lactam/β-lactamase inhibitor combo	Piperacillin/tazobactam															13			0		1		0	0	14	7.1%
carbapenem	Imipenem						14				0			0			0	0							14	
fluoroquinolone	Enrofloxacin	14		0		0		0			0			0	0										14	0.0%
fluoroquinolone	Marbofloxacin	14		0		0		0			0			0	0										14	0.0%
fluoroquinolone	Orbifloxacin						14				0			0			0	0							14	0.0%
fluoroquinolone	Pradofloxacin		13	1		0		0			0	0													14	0.0%
folate pathway antagonist	Trimethoprim/sulfamethoxazole[§]				14			0			0			0	0										14	
penicillin	Ampicillin		0			0		12			0			0			0	2							14	
phenicol	Chloramphenicol									0				7			6		0		0	1			14	
tetracycline	Doxycycline		0			0		4			6			2			0	2							14	
tetracycline	Tetracycline												12				0		0	2					14	

Canine-specific interpretive criteria are indicated for selected antibiotics. Green shaded cells = sensitive, yellow shaded cells = intermediate and red shaded cells = resistant. Interpretive values are based on CLSI Vet08, 4th ed. (2018).

*Percentage of resistant isolates.

[T]Amoxicillin/clavulanic acid concentrations on plate are 0.25/0.12, 0.5/0.25, 1/0.5, 2/1, 4/2 and 8/4 µg/mL.

[§]Trimethoprim/sulfamethoxazole concentrations on plate are 0.12/2.38, 0.25/4.75, 0.5/9.5 µg/mL, 1/19, 2/38, and 4/76 µg/mL.

TABLE 35. CLINICAL SYMPTOMS AND DIAGNOSES ASSOCIATED WITH CANINE SALMONELLA SEROTYPES.

Diagnosis/clinical symptom	Count	%	Salmonella serotype
DIARRHEA/ENTERIC DISEASE	8	57.1%	Abony (1), Anatum (2), Give (1), Albany (1), Newport (1), Rough O:d:1,7 (1), Telekebir (1)
WOUND/INFECTION	2	14.3%	IIIb 38:k:z35 (1), Newport (1)
ENDOCARDITIS	1	7.1%	Typhimurium (1)
SEPTICEMIA	1	7.1%	III 44:z4,z32:- (1)
URINARY TRACT INFECTION	1	7.11%	Typhimurium (1)
OTHER*	1	7.1%	Thompson
TOTAL	14		

*Other diagnosis: *Salmonella* infection

Dogs - *Staphylococcus intermedius* group

DOGS – *S. INTERMEDIUS* GROUP - URINARY TRACT INFECTIONS-OX[S]

TABLE 36. MIC DISTRIBUTION FOR CANINE OXACILLIN-SENSITIVE S. INTERMEDIUS GROUP ISOLATES RECOVERED FROM URINARY TRACT INFECTIONS.

Antibiotic class	MIC value (µg/mL) / Antibiotic	<=0.06	0.06	<=0.12	0.12	<=0.25	0.25	<=0.5	0.5	>0.5	<=1	1	>1	<=2	2	>2	<=4	4	>4	<=8	8	>8	<=16	16	>16	32	>32	64	>64	Total Isolates	%R*
1st gen cephalosporin	Cefazolin					0					0			67	0			1	0										68	0.0%
1st gen cephalosporin	Cephalothin										0			68				0	0										68	
3rd gen cephalosporin	Cefovecin	1	0	0	33		29		3			2			0			0			0	0							68	
3rd gen cephalosporin	Cefpodoxime										0			67				1		0	0	0							68	
aminoglycoside	Amikacin																						68			0	0			68	0.0%
aminoglycoside	Gentamicin													0			63				1			3	1					68	
ansamycin	Rifampin										68				0	0														68	
β lactam/β-lactamase inhibitor combo	Amoxicillin/ Clavulanic acid**[T]			0		68			0			0			0			0			0	0								68	
carbapenem	Imipenem										68				0			0	0										68	
fluoroquinolone	Enrofloxacin					57	0		3			4			0			0	4										68	5.9%
fluoroquinolone	Marbofloxacin										64	0			0			0	4										68	5.9%
fluoroquinolone	Pradofloxacin[§]					64			0			0			4	0														68	5.9%
folate pathway antagonist	Trimethoprim/sulfamethoxazole[‡]										0			57				2	9										68	
lincosamide	Clindamycin							62				0			0			0	6										68	
macrolide	Erythromycin					44	1		16			0			0			0	7										68	
nitrofuran	Nitrofurantoin																			0			68	0		0		0	0	68	
penicillin	Ampicillin					55		0	7			1			2			2			1	0							68	
penicillin	Oxacillin°					68	0	0	0			0			0	0													68	
penicillin	Penicillin	26			6	1	13		5			4			2			3			3	5							68	
phenicol	Chloramphenicol																			64				0		0	4			68	
tetracycline	Doxycycline			44			6		0	17				1																68	
tetracycline	Minocycline							50				1			6	11														68	
tetracycline	Tetracycline					46			4			1	17		0			0	0										68	

Canine-specific interpretive criteria are indicated for selected antibiotics. Green shaded cells = sensitive, yellow shaded cells = intermediate and red shaded cells = resistant.

Interpretive values based on CLSI Vet08, 4th ed. (2018).

*Percentage of resistant isolates.

**Interpretive breakpoints for intermediate and resistant have not been established for amoxicillin/clavulanic acid in canine urinary tract infections.

§Pradofloxacin is not approved for use in dogs in the U.S.

†Amoxicillin/clavulanic acid concentrations on plate are 0.25/0.12, 0.5/0.25, 1/0.5, 2/1, 4/2 and 8/4 µg/mL.

‡Trimethoprim/sulfamethoxazole concentrations on plate are 2/38 and 4/76 µg/mL.

Human-derived breakpoints for oxacillin [S ≤0.25, R ≥0.5] were used to categorize oxacillin sensitive isolates.

DOGS – *S. INTERMEDIUS* GROUP - URINARY TRACT INFECTIONS-OX^{R}

TABLE 37. MIC DISTRIBUTION FOR CANINE OXACILLIN-RESISTANT S. INTERMEDIUS GROUP ISOLATES RECOVERED FROM URINARY TRACT INFECTIONS.

Antibiotic class	MIC value (µg/mL) / Antibiotic	<=0.06	0.06	<=0.12	0.12	<=0.25	0.25	<=0.5	0.5	>0.5	<=1	1	>1	<=2	2	>2	<=4	4	>4	<=8	8	>8	<=16	16	>16	32	>32	64	>64	Total Isolates	%R*
1st gen cephalosporin	Cefazolin**					0					0			5	0			0	5											10	
1st gen cephalosporin	Cephalothin**										0			5				1	4											10	
3rd gen cephalosporin	Cefovecin**	0	0	0	0		0		0			1			0			0			1	8							10	
3rd gen cephalosporin	Cefpodoxime**										0			1				0		0	0	9							10	
aminoglycoside	Amikacin																						8			2	0			10	20.0%
aminoglycoside	Gentamicin													0			6				4			0	0					10	
ansamycin	Rifampin										9				1	0														10	
β lactam/β-lactamase inhibitor combo	Amoxicillin/ Clavulanic acid**†			0		1			2			0			1			3			0	3								10	
carbapenem	Imipenem**										9				0			0	1											10	
fluoroquinolone	Enrofloxacin					2	0		2			0			0			1	5											10	60.0%
fluoroquinolone	Marbofloxacin										4	0			0			0	6											10	60.0%
fluoroquinolone	Pradofloxacin					4			0			1			4	1														10	50.0%
folate pathway antagonist	Trimethoprim/sulfamethoxazole‡										0			4				0	6											10	
glycopeptide	Vancomycin										10				0			0			0			0	0					10	
lincosamide	Clindamycin							3				1			0			0	6											10	
macrolide	Erythromycin					1	0		0			0			1			0	8											10	
nitrofuran	Nitrofurantoin																			0			9	0		1		0	0	10	
penicillin	Ampicillin**					0		0	1			0			0			0			1	8								10	
penicillin	Oxacillin§					0	0	0	0			1			0	9														10	
penicillin	Penicillin**	0			0	0	0		0			0			1			0			0	9								10	
phenicol	Chloramphenicol																			6				0		0	4			10	
tetracycline	Doxycycline			2			0		0	8				0																10	
tetracycline	Minocycline							2				0			1	7														10	
tetracycline	Tetracycline					2			0			0	8		0			0	0											10	

Canine-specific interpretive criteria are indicated for selected antibiotics. Green shaded cells = sensitive, yellow shaded cells = intermediate and red shaded cells = resistant. Interpretive values based on CLSI Vet08, 4th ed. (2018).

*Percentage of resistant isolates.

**Antibiotics that would be reported as resistant based on oxacillin resistance.

§Human-derived breakpoints for oxacillin [S ≤0.25, R ≥0.5] were used to categorize oxacillin sensitive isolates.

†Amoxicillin/clavulanic acid concentrations on plate are 0.25/0.12, 0.5/0.25, 1/0.5, 2/1, 4/2 and 8/4 µg/mL.

‡Trimethoprim/sulfamethoxazole concentrations on plate are 2/38 and 4/76 µg/mL.

TABLE 38. MIC DISTRIBUTION FOR CANINE OXACILLIN-SENSITIVE S. INTERMEDIUS GROUP ISOLATES RECOVERED FROM BODY SITES OTHER THAN URINARY TRACT INFECTIONS.

Antibiotic class	MIC value (µg/mL) / Antibiotic	<=0.06	0.06	<=0.12	0.12	<=0.25	0.25	<=0.5	0.5	>0.5	<=1	1	>1	<=2	2	>2	<=4	4	>4	<=8	8	>8	<=16	16	>16	32	>32	64	>64	Total Isolates	%R*
1st gen cephalosporin	Cefazolin					0					1			267	0			0	0											268	0.0%
1st gen cephalosporin	Cephalothin										1			266				1	0											268	0.0%
3rd gen cephalosporin	Cefovecin	4	1	1	121		132		5			4			0			0			0	0							268	0.0%
3rd gen cephalosporin	Cefpodoxime**										1			265				2		0	0	0							268	0.0%
aminoglycoside	Amikacin†																			1			266			0	1			268	0.4%
aminoglycoside	Gentamicin													1			229				12			13	13					268	
ansamycin	Rifampin							1			267				0	0														268	
B lactam/B-lactamase inhibitor combo	Amoxicillin/ Clavulanic acid‡			1		265			2			0			0			0			0	0								268	0.0%
carbapenem	Imipenem							1			267				0			0	0											268	
fluoroquinolone	Enrofloxacin					225	1		7			19			1			0	15											268	5.6%
fluoroquinolone	Marbofloxacin							1			250	1			1			0	15											268	5.6%
fluoroquinolone	Pradofloxacin§			1		251			2			0			8	6														268	5.2%
folate pathway antagonist	Trimethoprim/sulfamethoxazole^										1			226				4	37											268	
glycopeptide	Vancomycin							1			263				4			0			0			0	0					268	
lincosamide	Clindamycin					1		224				2			0			3	38											268	15.3%
macrolide	Erythromycin			1		166	0		55			2			0			0	44											268	
nitrofuran	Nitrofurantoin																			1			267	0		0		0	0	268	
penicillin	Ampicillin			1		162		2	36			29			16			11			7	4								268	39.2%
penicillin	Oxacillin°					267	1	0	0			0			0	0														268	
penicillin	Penicillin	89			4	2	25		14			18			13			27			25	51								268	
phenicol	Chloramphenicol																1			241				8		1	17			268	
tetracycline	Doxycycline	1		174			16		4	73																				268	28.7%
tetracycline	Minocycline					1		190				6			12	59														268	26.5%
tetracycline	Tetracycline			1		178			12			3	74		0			0	0											268	28.7%

Canine-specific interpretive criteria are indicated for selected antibiotics. Green shaded cells = sensitive, yellow shaded cells = intermediate and red shaded cells = resistant. Interpretive values based on CLSI Vet08, 4th ed. (2018).

*Percentage of resistant isolates.

** Cefpodoxime breakpoints are established for wounds, abscesses and urinary tract infections only in dogs.

† Antibiotic sensitivity plate dilutions for amikacin are 16 and 32 µg/mL. Canine amikacin breakpoints are ≤4 µg/mL [sensitive], 8 µg/mL [intermediate] and ≥16 µg/mL [resistant]. Isolates classified as resistant are in red.

‡Amoxicillin/clavulanic acid concentrations on plate are 0.25/0.12, 0.5/0.25, 1/0.5, 2/1, 4/2 and 8/4 µg/mL.

§Pradofloxacin is not approved for use in dogs in the U.S.

^Trimethoprim/sulfamethoxazole concentrations on plate are 2/38 and 4/76 µg/mL.

Human-derived breakpoints for oxacillin [S ≤0.25, R ≥0.5] were used to categorize oxacillin sensitive isolates.

TABLE 39. ANTIBIOTIC RESISTANCE ANALYSIS FOR CANINE OXACILLIN-SENSITIVE S. INTERMEDIUS GROUP NON-UTI ISOLATES.

		Number of resistant isolates by antibiotic class and individual antibiotic													
		AMINO-GLYCOSIDE	β LACTAM COMBO	CEPHALOSPORIN				FLUOROQUINOLONE			LINCOSAMIDE	PENICILLIN	TETRACYCLINE		
No. of antibiotic resistant phenotypes per isolate	No. isolates (% total)	Amikacin* No. resistant	Amoxicillin/-clavulanic acid No. resistant	Cefazolin No. resistant	Cefovecin No. resistant	Cefpodoxime No. resistant	Cephalothin No. resistant	Enrofloxacin No. resistant	Marbofloxacin No. resistant	Pradofloxacin No. resistant	Clindamycin No. resistant	Ampicillin No. resistant	Doxycycline No. resistant	Minocycline No. resistant	Tetracycline No. resistant
8	4 (1 5%)	0	0	0	0	0	0	4	4	4	4	4	4	4	4
7	5 (1 9%)	0	0	0	0	0	0	5	5	4 (1 intermediate susceptibility)	5	1	5	5	5
6	3 (1.1%)	1	0	0	0	0	0	2	2	2	0	1	3	3	3
5	12 (4 5%)	0	0	0	0 (1 intermediate susceptibility)	0	0	3 (3 intermediate susceptibility	3 (1 intermediate susceptibility)	3	13	11	9	9	10
4	25 (9 3%)	0	0 (1 intermediate susceptibility)	0	0 (2 intermediate susceptibility)	0	0	1 (5 intermediate susceptibility)	1	1	8	17	24	24	24
3	26 (9.7%)	0	0	0	0	0	0	0 (3 intermediate susceptibility	0	0	1	2	26	23 (2 intermediate susceptibility)	26
2	14 (5 2%)	0	0	0	0	0	0 (1 intermediate susceptibility)	0 (3 intermediate susceptibility	0	0	8	12	4 (2 intermediate susceptibility)	1 (3 intermediate susceptibility)	3 (3 intermediate susceptibility)
1	66 (24.6%)	0	0	0	0	0	0	0 (2 intermediate susceptibility)	0	0	2 (2 intermediate susceptibility)	57	2 (5 intermediate susceptibility)	2 (1 intermediate susceptibility)	2 (2 intermediate susceptibility)
0	113 (42.2%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	268	1	0	0	0	0	0	15	15	14	41	105	77	71	77

* Antibiotic sensitivity plate dilutions for amikacin are 16 and 32 µg/mL. Amikacin breakpoints for dogs are ≤4 µg/mL [sensitive], 8 µg/mL [intermediate] and ≥16 µg/mL [resistant]. Thus resistant isolates may be under-reported.

TABLE 40. CLINICAL SYMPTOMS AND DIAGNOSES ASSOCIATED WITH CANINE OXACILLIN-SENSITIVE S. INTERMEDIUS GROUP NON-UTI ISOLATES.

Clinical symptom/diagnosis	COUNT	%
ABSCESS/WOUND/SKIN INFECTION	147	54.9%
OTITIS/EAR INFECTION	61	22.8%
REPRODUCTIVE TRACT INFECTIONS	12	4.5%
UNDETERMINED	11	4.1%
OTHER*	7	2.6%
PERITONITIS/PARENCHYMAL ORGAN INFECTIONS	7	2.6%
PNEUMONIA/RESPIRATORY INFECTION	7	2.6%
ARTHRITIS/JOINT INFECTION	6	2.2%
EYE INFECTION	5	1.9%
SEPSIS/SEPTICEMIA	3	1.1%
MASTITIS	2	0.7%
TOTAL	268	

*Other diagnoses = hepatic lipidosis (1), pleuritis (1), cardiomyopathy (1), canine herpesvirus (1), heartworm (1), and epiglottitis (2).

TABLE 41. MIC DISTRIBUTION FOR CANINE OXACILLIN-RESISTANT S. INTERMEDIUS GROUP ISOLATES RECOVERED FROM BODY SITES OTHER THAN URINARY TRACT INFECTIONS.

Antibiotic class	MIC value (µg/mL) / Antibiotic	<=0.06	0.06	<=0.12	0.12	<=0.25	0.25	<=0.5	0.5	>0.5	<=1	1	>1	<=2	2	>2	<=4	4	>4	<=8	8	>8	<=16	16	>16	32	>32	64	>64	Total Isolates	%R*
1st gen cephalosporin	Cefazolin**					1					0			117	0			5	23										146	
1st gen cephalosporin	Cephalothin**										0			124				4	18										146	
3rd gen cephalosporin	Cefovecin**	0	0	0	0		5		4			14			18			27			12	66							146	
3rd gen cephalosporin	Cefpodoxime**										1			38				15		1	5	85							145	
aminoglycoside	Amikacin[§]																			0			142			0	4			146	2.7%
aminoglycoside	Gentamicin													0			61				35			20	30					146	
ansamycin	Rifampin							0			138				2	6														146	
β lactam/β-lactamase inhibitor combo	Amoxicillin/ Clavulanic acid**[†]			0		18			55			27			14			10			14	8								146	
carbapenem	Imipenem**							0			144				1			0	1										146	
fluoroquinolone	Enrofloxacin					24	0		5			10			4			2	101										146	70.5%
fluoroquinolone	Marbofloxacin							2			41	0			0			5	98										146	70.5%
fluoroquinolone	Pradofloxacin			0		40			5			4			61	36														146	66.4%
folate pathway antagonist	Trimethoprim/sulfamethoxazole[‡]										0			39				20	87										146	
glycopeptide	Vancomycin							0			141				3			0			0			0	2				146	
lincosamide	Clindamycin					0		37				0			0			0	109										146	74.7%
macrolide	Erythromycin			0		25	0		13			1			0			0	107										146	
nitrofuran	Nitrofurantoin																			0			142	0		2		0	2	146	
penicillin	Ampicillin**			0		4		0	2			7			10			15			22	86								146	
penicillin	Oxacillin°					0	0	1	24			37			15	69														146	
penicillin	Penicillin**	1			0	0	3		0			1			3			8			10	120								146	
phenicol	Chloramphenicol																0			103				25		2	16			146	
tetracycline	Doxycycline	0		28			4		2	112																				146	78.1%
tetracycline	Minocycline					1		29				5			5	106														146	76.0%
tetracycline	Tetracycline			0		29			3			2	112		0			0	0											146	78.1%

Canine-specific interpretive criteria are indicated for selected antibiotics. Green shaded cells = sensitive, yellow shaded cells = intermediate and red shaded cells = resistant. Interpretive values based on CLSI Vet08, 4th ed. (2018).

*Percentage of resistant isolates.

**Antibiotics that would be reported as resistant based on oxacillin resistance.

[§]Antibiotic sensitivity plate dilutions for amikacin are 16 and 32 µg/mL. Canine amikacin breakpoints are ≤4 µg/mL [sensitive], 8 µg/mL [intermediate] and ≥16 µg/mL [resistant]. Isolates classified as resistant are in red.

[†] Amoxicillin/clavulanic acid concentrations on plate are 0.25/0.12, 0.5/0.25, 1/0.5, 2/1, 4/2 and 8/4 µg/mL.

[‡]Trimethoprim/sulfamethoxazole concentrations on plate are 2/38 and 4/76 µg/mL.

Human-derived breakpoints for oxacillin [S ≤0.25, R ≥0.5] were used to categorize oxacillin resistant isolates.

TABLE 42. ANTIBIOTIC RESISTANCE ANALYSIS FOR CANINE OXACILLIN-RESISTANT S. INTERMEDIUS GROUP NON-UTI ISOLATES.

		Number of resistant isolates by antibiotic class and individual antibiotic*							
		AMINO-GLYCOSIDE	LINCOSAMIDE	FLUOROQUINOLONE			TETRACYCLINE		
No. of antibiotic resistant phenotypes per isolate	No. isolates (% total)	Amikacin** No. resistant	Clindamycin No. resistant	Enrofloxacin No. resistant	Marbofloxacin No. resistant	Pradofloxacin No. resistant	Doxycycline No. resistant	Minocycline No. resistant	Tetracycline No. resistant
8	1 (0.7%)	1	1	1	1	1	1	1	1
7	77 (52.7%)	0	77	77	77	77	77	77	77
6	10 (6.8%)	0	2	10	9	9 (1 intermediate susceptibility)	10	10	10
5	3 (2.1%)	1	2	2 (1 intermediate susceptibility)	3	1 (2 intermediate susceptibility)	3	1 (1 intermediate susceptibility)	2
4	20 (13.7%)	1	19	6 (5 intermediate susceptibility)	5	5 (1 intermediate susceptibility)	15	14 (1 intermediate susceptibility)	15
3	14 (9.6%)	1	2	5 (2 intermediate susceptibility)	6	4 (3 intermediate susceptibility)	8	8 (1 intermediate susceptibility)	8 (1 intermediate susceptibility)
2	1 (0.7%)	0	0	1	1	0 (1 intermediate susceptibility)	0	0	0
1	8 (5.5%)	0	6	1 (1 intermediate susceptibility	1	0 (1 intermediate susceptibility)	0 (1 intermediate susceptibility)	0	1
0	12 (8.2%)	0	0	0 (4 intermediate susceptibility)	0	0	0 (2 intermediate susceptibility)	0 (1 intermediate susceptibility)	0 (1 intermediate susceptibility)
TOTAL	146	4	109	103	103	97	114	111	114

* Antibiotics that would be reported as resistant based on oxacillin resistance were not analyzed.

** Antibiotic sensitivity plate dilutions for amikacin are 16 and 32 µg/mL. Amikacin breakpoints for dogs are ≤4 µg/mL [sensitive], 8 µg/mL [intermediate] and ≥16 µg/mL [resistant]. Thus resistant isolates may be under-reported.

TABLE 43. CLINICAL SYMPTOMS AND DIAGNOSES ASSOCIATED WITH CANINE OXACILLIN-RESISTANT S. INTERMEDIUS GROUP NON-UTI ISOLATES.

Clinical symptom/diagnosis	COUNT	%
ABSCESS/WOUND/SKIN INFECTIONS	76	52.1%
OTITIS/EAR INFECTION	42	28.8%
ARTHRITIS/JOINT INFECTION	10	6.8%
PNEUMONIA/RESPIRATORY INFECTION	7	4.8%
UNDETERMINED	4	2.7%
OTHER*	4	2.7%
REPRODUCTIVE TRACT INFECTIONS	2	1.4%
SEPSIS/SEPTICEMIA	1	0.7%
TOTAL	146	

*Other diagnoses were cornea infection (1), gastritis (1), stomatitis (1), urinary obstruction (1), and no diagnosis given (1).

APPENDIX F: Cats MIC Distributions, Salmonella Serotypes and Clinical Symptoms

CATS - *E. COLI*

TABLE 44. MIC DISTRIBUTION FOR E. COLI UTI ISOLATES RECOVERED FROM CATS.

antibiotic class	MIC value (µg/mL) / Antibiotic	<=0.12	<=0.25	0.25	<=0.5	0.5	<=1	1	<=2	2	>2	<=4	4	>4	<=8	8	>8	16	>16	32	>32	64	>64	Total Isolates	%R*
1st gen cephalosporin	Cefazolin						77			83			15			4		3		1	15			198	
1st gen cephalosporin	Cephalexin				0			0		4			85			82		7	20					198	
3rd gen cephalosporin	Cefovecin**		23			106		42		10			1			0	16							198	8.1%
3rd gen cephalosporin	Cefpodoxime§						177	1		0			1			3	16							198	
3rd gen cephalosporin	Ceftazidime§											185				0		7	6					198	
aminoglycoside	Amikacin											193				3		0		1	1			198	
aminoglycoside	Gentamicin		3			92		87		3			2			1	10							198	
β lactam/β-lactamase inhibitor combo	Amoxicillin/ Clavulanic acid †		0			0		6		31			99			41	21							198	100.0%
β lactam/β-lactamase inhibitor combo	Piperacillin/tazobactam														196			2		0		0	0	198	
fluoroquinolone	Enrofloxacin	177		4		1		2		2			0	12										198	
fluoroquinolone	Marbofloxacin	178		1		4		2		0			1	12										198	
fluoroquinolone	Orbifloxacin						181			1			1			2	13							198	
fluoroquinolone	Pradofloxacin		181	1		3		1		0	12													198	
folate pathway antagonist	Trimethoprim/sulfamethoxazole‡				191			0		0			0	7										198	
penem	Imipenem						197			1			0			0	0							198	
penicillin	Ampicillin		1			1		11		71			51			5	58							198	99.0%
phenicol	Chloramphenicol								3				67			105		17		1	5			198	
tetracycline	Doxycycline		3			14		82		67			16			4	12							198	
tetracycline	Tetracycline											181				0		1	16					198	

Feline-specific interpretive criteria are indicated for selected antibiotics. Green shaded cells = sensitive, yellow shaded cells = intermediate and red shaded cells = resistant. Interpretive values are based on CLSI Vet08, 4th ed. (2018).

*Percentage of resistant isolates.

** Cefovecin only has feline *E. coli* breakpoints for urinary tract infections.

§ Extended spectrum β lactamase (ESBL) testing is indicated for isolates with cefpodoxime MIC ≥ 8 µg/ml, or >2 µg/ml for ceftazidime (highlighted in blue)

† Amoxicillin/clavulanic acid concentrations on plate are 0.25/0.12, 0.5/0.25, 1/0.5, 2/1, 4/2 and 8/4 µg/mL.

‡Trimethoprim/sulfamethoxazole concentrations on plate are 2/38 and 4/76 µg/mL.

TABLE 45. MIC DISTRIBUTION FOR E. COLI NON-UTI ISOLATES RECOVERED FROM CATS.

antibiotic class	MIC value (µg/mL) / Antibiotic	<=0.12	<=0.25	0.25	<=0.5	0.5	<=1	1	<=2	2	>2	<=4	4	>4	<=8	8	>8	16	>16	32	>32	64	>64	Total Isolates	%R*
1st gen cephalosporin	Cefazolin						29			19			7			2		1		0	10			68	
1st gen cephalosporin	Cephalexin				0			0		0			35			18		3	12					68	
3rd gen cephalosporin	Cefovecin		3			39		15		1			1			0	9							68	
3rd gen cephalosporin	Cefpodoxime**						57	0		0			1			1	9							68	

3rd gen cephalosporin	Ceftazidime**											59				2		6	1					68	
aminoglycoside	Amikacin											66				2		0		0	0			68	
aminoglycoside	Gentamicin		1			35		27		3			1			0	1							68	
β lactam/β-lactamase inhibitor combo	Amoxicillin/ Clavulanic acid †		0			0		1		7			37			11	12							68	100.0%
β lactam/β-lactamase inhibitor combo	Piperacillin/tazobactam														67			0		0		0	1	68	
fluoroquinolone	Enrofloxacin	65		0		0		1		1			0	1										68	1.5%
fluoroquinolone	Marbofloxacin	64		1		1		1		0			0	1										68	1.5%
fluoroquinolone	Orbifloxacin						65			0			1			1	1							68	2.9%
fluoroquinolone	Pradofloxacin		66	0		0		1		0	1													68	1.5%
folate pathway antagonist	Trimethoprim/sulfamethoxazole‡				64			1		0			0	3										68	
penem	Imipenem						67			1			0			0	0							68	
penicillin	Ampicillin		0			0		2		23			18			1	24							68	100.0%
phenicol	Chloramphenicol								1				23			40		2		1	1			68	
tetracycline	Doxycycline		1			2		39		15			2			2	7							68	
tetracycline	Tetracycline											58				1		0	9					68	

Feline-specific interpretive criteria are indicated for selected antibiotics. Green shaded cells = sensitive, yellow shaded cells = intermediate and red shaded cells = resistant. Interpretive values are based on CLSI Vet08, 4th ed. (2018).

*Percentage of resistant isolates.

** Extended spectrum β lactamase (ESBL) testing is indicated for isolates with cefpodoxime MIC ≥ 8 µg/ml, or >2 µg/ml for ceftazidime (highlighted in blue)

† Amoxicillin/clavulanic acid concentrations on plate are 0.25/0.12, 0.5/0.25, 1/0.5, 2/1, 4/2 and 8/4 µg/mL.

‡Trimethoprim/sulfamethoxazole concentrations on plate are 2/38 and 4/76 µg/mL.

TABLE 46. CLINICAL SYMPTOMS AND DIAGNOSES ASSOCIATED WITH FELINE E. COLI NON-UTI ISOLATES.

Clinical symptom/diagnosis	COUNT	%
SKIN/WOUND INFECTIONS	14	20.6%
PNEUMONIA/RESPIRATORY INFECTION	12	17.6%
OTHER*	11	16.2%
PERITONITIS/PERYNCHAMOUS ORGAN INFECTIONS	11	16.2%
ENTERITIS/ENTERIC INFECTIONS	7	10.3%
REPRODUCTIVE TRACT INFECTIONS	4	5.9%
UNDETERMINED	4	5.9%
OTITIS/EAR INFECTIONS	3	4.4%
SEPSIS/SEPTICEMIA	2	2.9%
TOTAL	68	

*Other diagnoses = cancer (2), feline panleukopenia (4), mastitis (1) lymphadenopathy (1), parvovirus (1), corneal sequestrum (1), and IBD (1).

Cats - *Salmonella* spp.

TABLE 47. MIC DISTRIBUTION FOR SALMONELLA ISOLATES RECOVERED FROM CATS.

antibiotic class	MIC value Antibiotic	<=0.12	<=0.25	0.25	<=0.5	0.5	<=1	1	<=2	2	>2	<=4	4	>4	<=8	8	>8	16	>16	32	>32	64	>64	Total Isolates	%R*
1st gen cephalosporin	Cefazolin						0			2			0			0		0		0	2			4	

1st gen cephalosporin	Cephalexin				0			0		0			2			0		0	2					4		
3rd gen cephalosporin	Cefovecin		0			0		2		0			0			0	2							4		
3rd gen cephalosporin	Cefpodoxime						2			0			0			0	2							4		
3rd gen cephalosporin	Ceftazidime										4					0		0	0					4		
aminoglycoside	Amikacin										4					0		0		0	0			4		
aminoglycoside	Gentamicin MIC		1			1		0		0			0			0	2							4		
β lactam/β lactamase inhibitor combo	Amoxicillin/ Clavulanic acid**		0			0		2		0			0			2	0							4		
β lactam/β lactamase inhibitor combo	Piperacillin/tazobactam§														4			0		0		0	0	4		
carbapenem	Imipenem						4			0			0			0	0							4		
fluoroquinolone	Enrofloxacin	2		0		2		0		0			0	0										4	0.0%	
fluoroquinolone	Marbofloxacin	2		2		0		0		0			0	0										4	0.0%	
fluoroquinolone	Orbifloxacin						4			0			0			0	0							4	0.0%	
fluoroquinolone	Pradofloxacin		4			0		0		0	0													4		
folate pathway antagonist	Trimethoprim/sulfamethoxazole†				4			0		0			0	0										4		
penicillin	Ampicillin		0			0		2		0			0			0	2							4		
phenicol	Chloramphenicol								0				1			3		0		0	0			4		
tetracycline	Doxycycline		0			0		2		0			0			0	2							4		
tetracycline	Tetracycline										2					0		0	2					4		

Feline-specific interpretive criteria are indicated for selected antibiotics. Green shaded cells = sensitive, yellow shaded cells = intermediate and red shaded cells = resistant. Interpretive values based on CLSI Vet08, 4th ed. (2018). *Percentage of resistant isolates.

Feline-specific interpretive criteria are indicated for selected antibiotics. Green shaded cells = sensitive, yellow shaded cells = intermediate and red shaded cells = resistant. Interpretive values are based on CLSI Vet08, 4th ed. (2018).
*Percentage of resistant isolates.
**Amoxicillin/clavulanic acid concentrations on plate are 0.25/0.12, 0.5/0.25, 1/0.5, 2/1, 4/2 and 8/4 µg/mL.
†Trimethoprim/sulfamethoxazole concentrations on plate are 2/38 and 4/76 µg/mL.

Cats - *S. intermedius* group

CATS – *S. INTERMEDIUS* GROUP - URINARY TRACT INFECTIONS-OX[S]

TABLE 48. MIC DISTRIBUTION FOR FELINE OXACILLIN-SENSITIVE S. INTERMEDIUS GROUP ISOLATES RECOVERED FROM URINARY TRACT INFECTIONS.

antibiotic class	MIC value (µg/mL) / Antibiotic	<=0.06	<=0.12	0.12	<=0.25	0.25	<=0.5	0.5	>0.5	<=1	1	>1	<=2	2	>2	<=4	4	>4	<=8	8	>8	<=16	16	>16	32	>32	64	>64	Total Isolates	%R*
1st gen cephalosporin	Cefazolin				0								14	0			0	0										14	
1st gen cephalosporin	Cephalothin												14				0	0										14	
3rd gen cephalosporin	Cefovecin	1		3		7		2			1			0			0			0	0							14	
3rd gen cephalosporin	Cefpodoxime												14				0		0	0	0							14	
aminoglycoside	Amikacin																					14			0	0			14	
aminoglycoside	Gentamicin															13				1			0	0					14	
ansamycin	Rifampin									14				0	0														14	
β lactam/β-lactamase inhibitor combo	Amoxicillin/ Clavulanic acid				14			0			0			0			0			0	0								14	0.0%

carbapenem	Imipenem									14				0			0	0											14	
fluoroquinolone	Enrofloxacin				13			0			0			0			0	1											14	
fluoroquinolone	Marbofloxacin									13				0			0	1											14	
fluoroquinolone	Pradofloxacin				13			0			0			1	0													14	
folate pathway antagonist	Trimethoprim/ sulfamethoxazole												12				1	1											14	
glycopeptide	Vancomycin									13				1			0			0			0	0					14	
lincosamide	Clindamycin				0		11				0			0			0	3											14	
macrolide	Erythromycin				8			3			0			0			0	3											14	
nitrofuran	Nitrofurantoin																					14			0		0	0	14	
penicillin	Ampicillin				11			1			1			1			0			0	0								14	14.3 %
penicillin	Oxacillin				14			0			0			0	0														14	
penicillin	Penicillin	9		1	0	0		0			1			1			1			1	0								14	
phenicol	Chloramphenicol																		13				0		0	1			14	
tetracycline	Doxycycline		7			2		0	5																				14	
tetracycline	Minocycline						10				0			1	3														14	
tetracycline	Tetracycline				7			2			0	5		0			0	0											14	

Feline-specific interpretive criteria are indicated for selected antibiotics. Green shaded cells = sensitive, yellow shaded cells = intermediate and red shaded cells = resistant. Interpretive values are based on CLSI Vet08, 4th ed. (2018).

*Percentage of resistant isolates.

† Amoxicillin/clavulanic acid concentrations on plate are 0.25/0.12, 0.5/0.25, 1/0.5, 2/1, 4/2 and 8/4 µg/mL.

‡Trimethoprim/sulfamethoxazole concentrations on plate are 2/38 and 4/76 µg/mL.

CATS – *S. INTERMEDIUS* GROUP – NON-URINARY TRACT INFECTIONS-OX[S]

TABLE 49. MIC DISTRIBUTION FOR FELINE OXACILLIN-SENSITIVE S. INTERMEDIUS GROUP ISOLATES RECOVERED FROM NON-URINARY TRACT INFECTIONS.

antibiotic class	MIC value (µg/mL) / Antibiotic	<=0.06	<=0.12	0.12	<=0.25	0.25	<=0.5	0.5	>0.5	<=1	1	>1	<=2	2	>2	<=4	4	>4	<=8	8	>8	<=16	16	>16	32	>32	64	>64	Total Isolates	%R*
1st gen cephalosporin	Cefazolin**				0								23	0			0	0											23	
1st gen cephalosporin	Cephalothin**												22				0	1											23	
3rd gen cephalosporin	Cefovecin**	1		7		13		1			1			0			0			0	0								23	
3rd gen cephalosporin	Cefpodoxime**												22				0		0	0	1								23	
aminoglycoside	Amikacin																					22			0	1			23	
aminoglycoside	Gentamicin															19				0			3	1					23	
ansamycin	Rifampin									23				0	0														23	
β lactam/β-lactamase inhibitor combo	Amoxicillin/ Clavulanic acid** †				22			1			0			0			0			0	0								23	0.0%
carbapenem	Imipenem									23				0			0	0											23	
fluoroquinolone	Enrofloxacin				20			1			0			0			0	2											23	8.7%

fluoroquinolone	Marbofloxacin									21				0			0	2											23	8.7%
fluoroquinolone	Pradofloxacin				20			0			1			1	1														23	8.7%
folate pathway antagonist	Trimethoprim/ sulfamethoxazole‡												19				0	4											23	
glycopeptide	Vancomycin									21				2			0			0			0	0					23	
lincosamide	Clindamycin				1		17				0			0			0	5											23	
macrolide	Erythromycin				11			5			1			0			0	6											23	
nitrofuran	Nitrofurantoin																					22			0		1	0	23	
penicillin	Ampicillin**				15			1			3			2			1			1	0								23	30.4%
penicillin	Oxacillin§				23			0			0			0	0														23	
penicillin	Penicillin**	5		3	0	3		2			1			1			0			4	4								23	
phenicol	Chloramphenicol																		22				1		0	0			23	
tetracycline	Doxycycline		13			1		0	9																				23	
tetracycline	Minocycline						14				0			2	7														23	
tetracycline	Tetracycline				13			1			0	9		0			0	0											23	

Feline-specific interpretive criteria are indicated for selected antibiotics. Green shaded cells = sensitive, yellow shaded cells = intermediate and red shaded cells = resistant. Interpretive values based on CLSI Vet08, 4th ed. (2018).

*Percentage of resistant isolates.

**Antibiotics that would be reported as resistant based on oxacillin resistance.

† Amoxicillin/clavulanic acid concentrations on plate are 0.25/0.12, 0.5/0.25, 1/0.5, 2/1, 4/2 and 8/4 µg/mL.

‡Trimethoprim/sulfamethoxazole concentrations on plate are 2/38 and 4/76 µg/mL.

§Human-derived breakpoints for oxacillin [S ≤0.25, R ≥0.5] were used to categorize oxacillin resistant isolates.

TABLE 50. CLINICAL SYMPTOMS AND DIAGNOSES ASSOCIATED WITH FELINE OXACILLIN-SENSITIVE S. INTERMEDIUS GROUP ISOLATES FROM NON-URINARY TRACT INFECTIONS.

Clinical symptom/diagnosis	COUNT	%
ABSCESS/SKIN/WOUND INFECTION	12	54.5%
OTITIS/EAR INFECTION	6	27.3%
RESPIRATORY INFECTION/PNEUMONIA	3	13.6%
OTHER/UNDETERMINED*	2	9.1%
TOTAL	23	

* Other diagnoses = peritonitis (1), mammary gland infection (1), no diagnosis given (1).

CATS – *S. INTERMEDIUS* GROUP – NON-URINARY TRACT INFECTIONS-OX^R

TABLE 51. MIC DISTRIBUTION FOR FELINE OXACILLIN-RESISTANT S. INTERMEDIUS GROUP ISOLATES RECOVERED FROM NON-URINARY TRACT INFECTIONS.

antibiotic class	MIC value (µg/mL) / Antibiotic	<=0.06	<=0.12	0.12	<=0.25	0.25	<=0.5	0.5	>0.5	<=1	1	>1	<=2	2	>2	<=4	4	>4	<=8	8	>8	<=16	16	>16	32	>32	64	>64	Total Isolates	%R*
1st gen cephalosporin	Cefazolin**				0								15	0			2	2										19	
1st gen cephalosporin	Cephalothin**												17				0	2										19	
3rd gen cephalosporin	Cefovecin**	0		0		0		1			1			5			1			7	4							19	
3rd gen cephalosporin	Cefpodoxime**												5				5		0	1	8							19	
aminoglycoside	Amikacin																					19			0	0			19	
aminoglycoside	Gentamicin															12				3			2	2					19	

ansamycin	Rifampin									19				0	0													19	
β lactam/β-lactamase inhibitor combo	Amoxicillin/ Clavulanic acid** †				4			3			6			0			3			1	2							19	
carbapenem	Imipenem**									19				0			0	0										19	
fluoroquinolone	Enrofloxacin				3			0			3			1			1	11										19	63.2%
fluoroquinolone	Marbofloxacin									6				0			1	12										19	68.4%
fluoroquinolone	Pradofloxacin				7			1			1			8	2													19	52.6%
folate pathway antagonist	Trimethoprim/ sulfamethoxazole‡												7				1	11										19	
glycopeptide	Vancomycin									19				0			0			0			0	0				19	
lincosamide	Clindamycin				0		6				0			0			0	13										19	
macrolide	Erythromycin				3			2			0			0			0	14										19	
nitrofuran	Nitrofurantoin																					19			0		0	0	19	
penicillin	Ampicillin**				0			1			3			1			1			5	8							19	
penicillin	Oxacillin§				0			6			2			1	10													19	
penicillin	Penicillin**	0		0	0	1		0			1			2			1			2	12							19	
phenicol	Chloramphenicol																		16				1		0	2			19	
tetracycline	Doxycycline		8			2		0	9																				19	
tetracycline	Minocycline						10				0			1	8														19	
tetracycline	Tetracycline				8			2			0	9		0			0	0											19	

Feline-specific interpretive criteria are indicated for selected antibiotics. Green shaded cells = sensitive, yellow shaded cells = intermediate and red shaded cells = resistant. Interpretive values based on CLSI Vet08, 4th ed. (2018).

*Percentage of resistant isolates.

**Antibiotics that would be reported as resistant based on oxacillin resistance.

† Amoxicillin/clavulanic acid concentrations on plate are 0.25/0.12, 0.5/0.25, 1/0.5, 2/1, 4/2 and 8/4 µg/mL.

‡Trimethoprim/sulfamethoxazole concentrations on plate are 2/38 and 4/76 µg/mL.

§Human-derived breakpoints for oxacillin [S ≤0.25, R ≥0.5] were used to categorize oxacillin resistant isolates.

TABLE 52. CLINICAL SYMPTOMS AND DIAGNOSES ASSOCIATED WITH FELINE OXACILLIN-RESISTANT S. INTERMEDIUS GROUP ISOLATES FROM NON-URINARY TRACT INFECTIONS.

Cat - *S. intermedius* group - oxacillin resistant - diagnosis	COUNT	%
ABSCESS/SKIN/WOUND INFECTION	13	68.4%
RESPIRATORY INFECTION/PNEUMONIA	2	10.5%
OTHER/UNDETERMINED*	2	10.5%
OTITIS/EAR INFECTION	2	10.5%
TOTAL	19	

* Other diagnoses – infected mast cell tumor (1), unknown diagnosis (1).

Appendix G. Epidemiological Cutoff Values (ECVs)

TABLE 53. ANTIMICROBIAL WILD-TYPE DISTRIBUTIONS FOR ESCHERICHIA COLI.

Antibiotic class	MIC value Antibiotic†	<=0.06	<=0.12	0.12	<=0.25	0.25	<=0.5	0.5	<=1	1	>1	<=2	2	>2	<=4	4	>4	<=8	8	>8	16	>16	20	>20	<=32	32	>32	64	>64	128	<=256	256	>256	Total Isolates*	% WT**
1st gen cephalosporin	Cefazolin								197				312		149	58			24		12	34				2	125							913	
1st gen cephalosporin	Cephalexin						0			0			6			221			323		34	140												724	80.7%
3rd gen cephalosporin	Cefovecin				50	1		303		198			37			9			2	124														724	
3rd gen cephalosporin	Cefpodoxime								579	1			4			9			6	125														724	80.7%
3rd gen cephalosporin	Ceftazidime								167				7		625	1			17		49	39				5		2	1					913	0.0%
3rd gen cephalosporin	Ceftiofur				231			473		20			13			9	62		44	124														976	74.2%
aminocoumarin	Novobicin						0			0			0			2	270																		272	
aminocyclitol	Spectinomycin																	53			432				50		34	218						787	
aminoglycoside	Amikacin								2						875	0			31		2				1	2								913	99.5%
aminoglycoside	Gentamicin				21	1	108	355	547	344			39			11			17	161	13	83												1700	83.2%
aminoglycoside	Neomycin											219	0		345	3			7		9				34	170							787	72.9%
aminoglycoside	Streptomycin																	152			12				15		36		36		14	7	272	60.3%
ansamycin	Rifampin								0				1	1		82	105																	189	
β lactam/β-lactamase inhibitor combo	Amoxicillin/Clavulanic acid				0			0		12			77			361			140	134														724	
β lactam/β-lactamase inhibitor combo	Piperacillin/tazobactam																	704			10				6		1	3						724	97.2%
β lactam/β-lactamase inhibitor combo	Ticarcillin																	134			4				0		2	49						189	73.0%
β lactam/β-lactamase inhibitor combo	Ticarcillin/Clavulanic acid																	149			14				14		6	6						189	86.2%
carbapenem	Imipenem								910				2			1			0	0														913	§
fluoroquinolone	Danofloxacin		374			8		20		5	108		0																					515	
fluoroquinolone	Enrofloxacin		1214		170	43		33		24			22	108		1	85																	1700	71.4%
fluoroquinolone	Marbofloxacin		591			15		24		7			0			2	85																	724	
fluoroquinolone	Orbifloxacin								614				13			6			4	87														724	
fluoroquinolone	Pradofloxacin				625			10		2			5	81																				723	
folate pathway antagonist	Sulfadimethoxine																							19	0		46		50	174	39	459	787	
folate pathway antagonist	Sulfathiazole																							136			21		4	1		110	272	
folate pathway antagonist	Trimethoprim/sulfa-methoxazole						979			12		331	7	208		6	157																1700	58.3%
lincosamide	Clindamycin				0		0	0		4			0			1	271		1			510												787	
macrolide	Azithromycin				0			0		7			60			97	25																	189	
macrolide	Clarithromycin								0				1			0			0	188														189	
macrolide	Erythromycin	1	1			1		0		0			0			0	271		0	188														461	
macrolide	Gamithromycin								3				4			30			91	29														157	
macrolide	Tildipirosin								2				13			93			39	0	3	7												157	
macrolide	Tilmicosin											0			0	1			2		1	155				26		213	117					515	
macrolide	Tulathromycin								0				8			59		135	198		87				3		5	20						515	
macrolide	Tylosin						0			0			1			0	2		0		2		5	265		0	512							787	

penicillin	Ampicillin				2			5		37	1		367			374			37	245	4	305				2	49							1428	57.6%
penicillin	Amoxicillin				1			0		3			52			109			17	1	3	86												272	66.9%
penicillin	Oxacillin				0			0		1			0			0	188																	189	
penicillin	Penicillin		1	1		0		0		0			0			1			7	966														976	
phenicol	Chloramphenicol											12			79	187			477		74	1				9	74								913	90.8%
phenicol	Florfenicol				1			0	0	3			156			387			63	177														787	100.0%
pleuromutilin	Tiamulin								0				0			1			0		3					22	489								515	
tetracycline	Chlortetracycline						2			16			45			33			12	250															358	
tetracycline	Doxycycline				5			25		239		130	268			73			35	95	11	32													913	81.1%
tetracycline	Oxytetracycline				0		1	1		99			122			11			1	395															630	
tetracycline	Tetracycline				0		0	3		100		136	66		596	3			9	306	3	120													1342	68.0%

MIC distribution data is collated across all 1700 *E. coli* isolate recovered from all animal species surveyed in the pilot project, and is not to be used to infer rates of resistance. Epidemiological cutoff values (ECVs) for individual antibiotics are indicated by blue-shaded boxes. No shading means no ECVs have been established for that antibiotic. ECVs were obtained from the European Committee on Antimicrobial Susceptibility Testing (EUCAST) MIC distribution website http://www.eucast.org, accessed on 17 February, 2019.

† All antibiotics present across all six antimicrobial sensitivity plates used for this pilot project were aggregated into one table.

*The total number *E. coli* of isolates were added together across all animal species. Numbers may differ for each agent due to different antibiotics being present on different antimicrobial sensitivity plates used in the pilot.

** Percentage of isolates that are classified as wild-type.

§The epidemiological cutoff value for imipenem in *E. coli* = 0.5 µg/mL. Because antimicrobial dilutions present on the commercial AST plates did not span this dilution, the percentage of wild type isolates could not be calculated.

TABLE 54. ANTIMICROBIAL WILD-TYPE DISTRIBUTIONS FOR SALMONELLA SPP.

Antibiotic class	MIC value Antibiotic	<=0.06	<=0.12	0.12	<=0.25	0.25	<=0.5	0.5	<=1	1	>1	<=2	2	>2	<=4	4	>4	<=8	8	>8	16	>16	20	>20	<=32	32	>32	64	>64	128	<=256	256	>256	Total Isolates*	% WT**
1st gen cephalosporin	Cefazolin								0				13		61	0			1		0	11				0	4							90	
1st gen cephalosporin	Cephalexin						0			0			0			12			2		0	4												18	
3rd gen cephalosporin	Cefovecin				1	0		6		6			1			0			0	4													18	
3rd gen cephalosporin	Cefpodoxime								14	0			0			0			0	4													18	
3rd gen cephalosporin	Ceftazidime								61				1		16	0			2		2	1				0		4	3					90	68.9%
3rd gen cephalosporin	Ceftiofur				4			79		278			32			5	13		26	129													566	69.4%
aminocoumarin	Novobicin						0			0			0			0	63																	63	
aminocyclitol	Spectinomycin																	4			99					258		64	69					494	
aminoglycoside	Amikacin								0						85	0			0		2					2	1							90	
aminoglycoside	Gentamicin				6	0	44	8	445	11			16			5			6	16	4	23												584	90.8%
aminoglycoside	Neomycin											61	0		338	2			4		3					3	83							494	81.2%
aminoglycoside	Streptomycin																	33			5					11		6		7		1	0	63	60.3%
ansamycin	Rifampin								0				0	0		1	71																	72	
B lactam/B-lactamase inhibitor combo	Amoxicillin/Clavulanic acid				0			0		14			0			0			2	2														18	
B lactam/B-lactamase inhibitor combo	Piperacillin/tazobactam																	17			0					1		0	0					18	94.4%
B lactam/B-lactamase inhibitor combo	Ticarcillin																	56			0					1		1	14					72	
B lactam/B-lactamase inhibitor combo	Ticarcillin/Clavulanic acid																	55	2		3					3		5	4					72	
carbapenem	Imipenem								89				1			0			0	0														90	98.9%
fluoroquinolone	Danofloxacin		359			9		29		23	11		0																					431	
fluoroquinolone	Enrofloxacin		431		69	11		35		11			17	10		0	0																	584	
fluoroquinolone	Marbofloxacin		16			2		0		0			0			0	0																	18	
fluoroquinolone	Orbifloxacin								18				0			0			0	0														18	
fluoroquinolone	Pradofloxacin				17	1		0		0			0	0																				18	
folate pathway antagonist	Sulphadimethoxine																							0	0		6		9	152	10	317	494	
folate pathway antagonist	Sulphathiazole																							26			24		4	1		8	63	
folate pathway antagonist	Trimethoprim/sulfamethoxazole						143			0		383	0	48		0	10																584	24.5%

lincosamide	Clindamycin				0		0	0		1			0			0	63		0			430														494	
macrolide	Azithromycin				0			0		0			9			50	13																			72	
macrolide	Clarithromycin								0				0			0			0	72																72	
macrolide	Erythromycin	0	0			0		0		0			0			0	63		0	72																135	
macrolide	Gamithromycin								0				1			47			73	8																129	
macrolide	Tildipirosin								0				0			10			74	0	38	7														129	
macrolide	Tilmicosin											0			0	0			0		1	128				1		35	266							431	
macrolide	Tulathromycin								0				0			16		83	166		117					43	1	1	4							431	
macrolide	Tylosin tartrate						0			0			0			1	0		1		0		0	62		1	429									494	
penicillin	Ampicillin				1			20		239	0		34			4			0	4	0	203				0	16									521	57.2%
penicillin	Amoxicillin				0			0		48			7			1			0	0	0	7														63	88.9%
penicillin	Oxacillin				0			0		0			0			0	72																			72	
penicillin	Penicillin		1	0		0		0		1			0			12			244	308																566	
phenicol	Chloramphenicol											0		29		8			37		2	0				0	14									90	84.4%
phenicol	Florfenicol				0			1	1	11			127			170			14	170																494	100.0%
pleuromutilin	Tiamulin								0				1			0			0		1					0	429									431	
tetracycline	Chlortetracycline						6			46			72			31			2	145																302	
tetracycline	Doxycycline				0			0		6		51	6			8			4	4	2	9														90	83.3%
tetracycline	Oxytetracycline				0		14	1		110			83			0			0	157																365	
tetracycline	Tetracycline				0		19	4		40		58	35		14	2			0	106	0	4														282	61.0%

MIC distribution data is collated across 584 *Salmonella* spp. isolates recovered from all animal species surveyed in the pilot project, and is not to be used to infer rates of resistance. Epidemiological cutoff values (ECVs) for individual antibiotics are indicated by blue-shaded boxes. No shading means no ECVs have been established for that antibiotic. ECVs were obtained from the European Committee on Antimicrobial Susceptibility Testing (EUCAST) MIC distribution website http://www.eucast.org, accessed on 17 February, 2019.

† All antibiotics present across all antimicrobial sensitivity plates used for this pilot project were aggregated into one table.

*The total number of *Salmonella spp.* isolates were added together across all animal species. Numbers may differ for each agent due to different antibiotics being present on different antimicrobial sensitivity plates used in the pilot.

** Percentage of isolates that are classified as wild-type.

TABLE 55. ANTIMICROBIAL WILD-TYPE DISTRIBUTIONS FOR MANNHEIMIA HAEMOLYTICA

Antibiotic class	MIC value Antibiotic	<=0.12	<=0.25	0.25	<=0.5	0.5	<=1	1	>1	<=2	2	>2	<=4	4	<=8	8	>8	16	>16	32	>32	64	>64	<=256	>256	Total Isolates*	% WT**
3rd gen cephalosporin	Ceftiofur		367			8		2			0			2		1	0									380	
aminocyclitol	Spectinomycin														8			88		215		6	63			380	
aminoglycoside	Gentamicin						58				234			29		4		3	52							380	
aminoglycoside	Neomycin												199			77		3		4	97					380	
fluoroquinolone	Danofloxacin	273		11		13		5	78																	380	
fluoroquinolone	Enrofloxacin	273		11		15		6			4	71														380	
folate pathway antagonist	Trimethoprim/sulfamethoxazole									373		7														380	
folate pathway antagonist	Sulphadimethoxine																							247	133	380	
lincosamide	Clindamycin		3			1		3			2			13		193		99	66							380	
macrolide	Gamithromycin						72				5			2		1	12									92	
macrolide	Tildipirosin						57				19			4		2		1	9							92	
macrolide	Tilmicosin									6			152	46		63		25	14	9		10	55			380	
macrolide	Tulathromycin						10				31			121	78	52		10		8		6	64			380	
macrolide	Tylosin				2			1			1			1		2		9		131	233					380	

penicillin	Ampicillin		301			19		4			2			2		4		9	39								380	
penicillin	Penicillin	153		114		34		21			3			3		4	48										380	
phenicol	Florfenicol		22			193		96			19			3		4	43										380	86.8%
pleuromutilin	Tiamulin				3			1			4			19		150		170		30	3						380	
tetracycline	Chlortetracycline				95			90			21			27		32	23										288	
tetracycline	Oxytetracycline				151			27			4			3		14	89										288	
tetracycline	Tetracycline				57			4			1			11		5	14										92	67.4%

MIC distribution data is collated across all 380 bovine *Mannheimia haemolytica* isolates during the first year of the pilot project. Data should not be used to infer rates of resistance. Epidemiological cutoff values (ECVs) for individual antibiotics are indicated by blue-shaded boxes. No shading means no ECVs have been established for that antibiotic. ECVs were obtained from the European Committee on Antimicrobial Susceptibility Testing (EUCAST) MIC distribution website http://www.eucast.org, accessed on 17 February, 2019.

† All antibiotics present on both the BOPO6F and BOPO7F antimicrobial sensitivity plates were aggregated into one table.

* Numbers may differ for each agent due to different antibiotics being present on different antimicrobial sensitivity plates used in the pilot.

** Percentage of isolates that are classified as wild-type.

ANTIMICROBIAL WILD-TYPE DISTRIBUTIONS FOR *STAPHYLOCOCCUS INTERMEDIUS* GROUP

TABLE 56. ANTIMICROBIAL WILD-TYPE DISTRIBUTIONS FOR STAPHYLOCOCCUS INTERMEDIUS GROUP.

Antibiotic class	MIC value Antibiotic	<=0.06	0.06	<=0.12	0.12	<=0.25	0.25	<=0.5	0.5	>0.5	<=1	1	>1	<=2	2	>2	<=4	4	>4	<=8	8	>8	<=16	16	>16	32	>32	64	>64	Total Isolates	% WT*
1st gen cephalosporin	Cefazolin					1					1			508	0			8	30										548	
1st gen cephalosporin	Cephalothin										1			516				6	25										548	
3rd gen cephalosporin	Cefovecin	7	1	1	164		186		16			24			23			28			20	78							548	
3rd gen cephalosporin	Cefpodoxime										2			412				23		1	6	103							547	
aminoglycoside	Amikacin																			1			539			2	6			548	
aminoglycoside	Gentamicin													1			403				56			41	47					548	
ansamycin	Rifampin							1			538				3	6														548	
B lactam/B-lactamase inhibitor combo	Amoxicillin/ Clavulanic acid			1		392			63			33			15			16			15	13							548	
carbapenem	Imipenem							1			544				1			0	2										548	
fluoroquinolone	Enrofloxacin					344	1		18			36			6			4	139										548	
fluoroquinolone	Marbofloxacin							3			399	1			1			6	138										548	
fluoroquinolone	Pradofloxacin			1		399			8			7			87	46													548	
folate pathway antagonist	Trimethoprim/sulfamethoxazole										1			364				28	155										548	
glycopeptide	Vancomycin							1			534				11			0			0			0	2				548	99.6%
lincosamide	Clindamycin					2		360				3			0			3	180										548	
macrolide	Erythromycin			1		258	1		94			4			1			0	189										548	65.3%
nitrofuran	Nitrofurantoin																			1			541	0		3		1	2	548	
penicillin	Ampicillin			1		247		2	49			44			32			30			37	106							548	
penicillin	Oxacillin					372	1	1	30			40			16	88													548	
penicillin	Penicillin	130			14	3	45		21			26			23			40			45	201							548	
phenicol	Chloramphenicol																1			465				35		3	44			548	91.4%
tetracycline	Doxycycline	1		276			31		6	233				1															548	
tetracycline	Minocycline					2		305				12			28	201													548	
tetracycline	Tetracycline			1		283			24			6	234		0			0	0										548	

MIC distribution data is collated across all 548 canine and feline *Staphylococcus intermedius* group isolates during the first year of the pilot project. Data should not be used to infer rates of resistance. Epidemiological cutoff values (ECVs) for individual antibiotics are indicated by blue-shaded boxes. No shading means no ECVs have been established for that antibiotic. ECVs were obtained from the European Committee on Antimicrobial Susceptibility Testing (EUCAST) MIC distribution website http://www.eucast.org, accessed on 17 February, 2019.

* Percentage of isolates that are classified as wild-type.

Appendix H. Acknowledgments

The following laboratories contributed data and isolates to the 2018 Year 1 APHIS AMR Pilot Project:

Alabama Auburn University College of Veterinary Medicine, Bacteriology & Mycology Diagnostic Laboratory

California Animal Health & Food Safety Laboratory System

Colorado State University Veterinary Diagnostic Laboratory

Florida Bronson Animal Disease Diagnostic Laboratory

Georgia Athens Veterinary Diagnostic Laboratory

Indiana Purdue Animal Disease Diagnostic Laboratory

University of Kentucky Veterinary Diagnostic Laboratory

Michigan State University Veterinary Diagnostic Laboratory

University of Minnesota Veterinary Diagnostic Laboratory

University of Missouri Veterinary Medical Diagnostic Laboratory

Mississippi Veterinary Research & Diagnostic Laboratory System

Nebraska Veterinary Diagnostic Center

New York Cornell University Animal Health Diagnostic Center

Ohio Department of Agriculture Animal Disease Diagnostic Laboratory

Pennsylvania Animal Diagnostic Laboratory System

South Dakota Animal Disease Research & Diagnostics Laboratory

Texas A&M Veterinary Medical Diagnostic Laboratory

Washington Animal Disease Diagnostic Laboratory

Wisconsin Veterinary Diagnostic Laboratory