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Veterinary Services

National Animal Health Monitoring System

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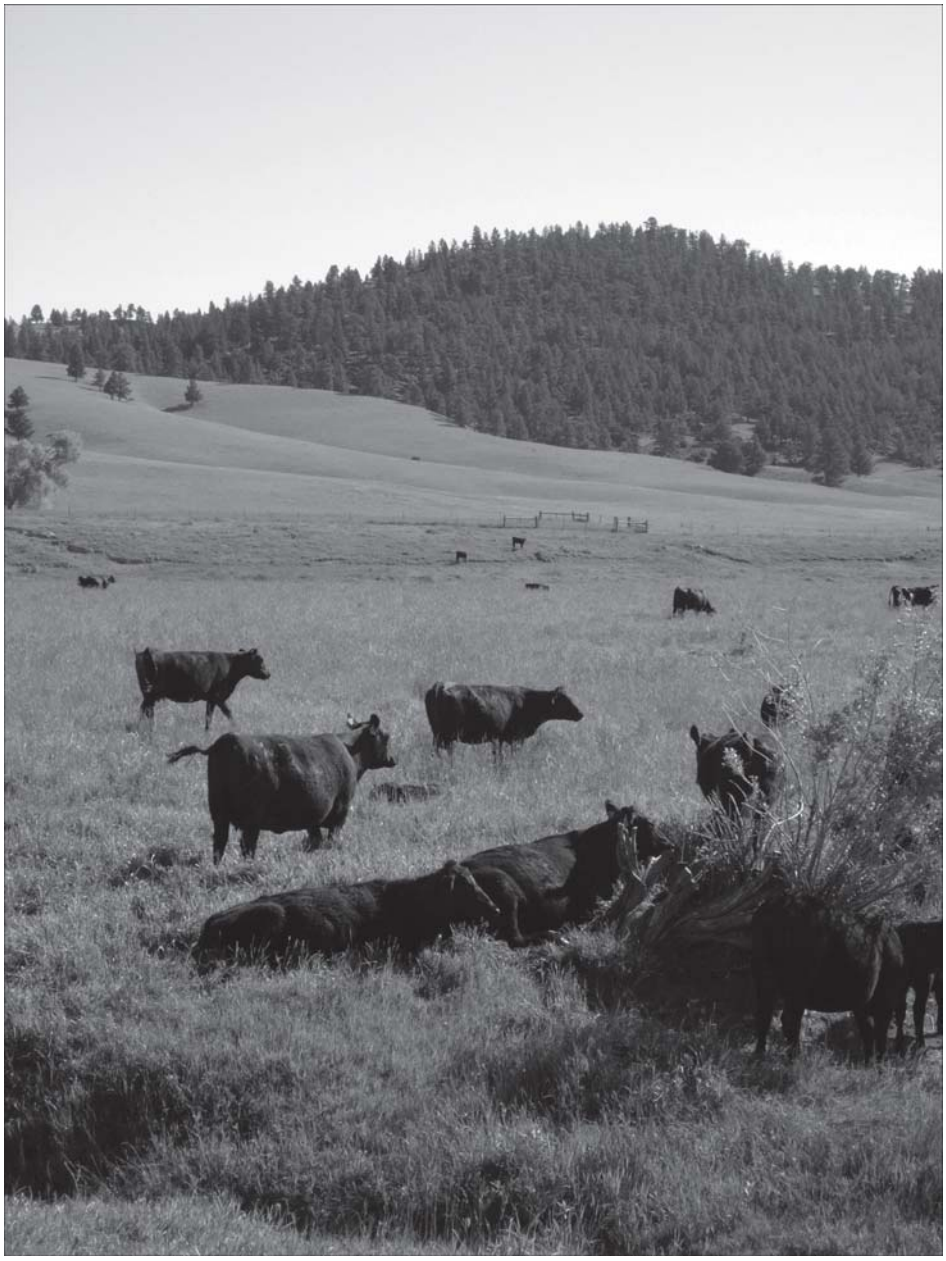
Beef 2007–08

Antimicrobial Drug Use and Antimicrobial Resistance on U.S. Cow-calf Operations, 2007–08



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Cover photo courtesy of Dr. Dave Dargatz

Items of Note

Organisms resistance to antimicrobial drugs, such as antiviral products, anthelmintics, and antibacterials, is a growing global concern. Much of this concern stems from the potential impacts on human health associated with resistant organisms, which is not to say that there is a lack of concern about the potential impact of resistant organisms on animal health and wellbeing. However, data on animal disease associated with resistant organisms are very limited.

There is also concern about antimicrobial drug use in animals and the impact such use could have on humans. People can be exposed to bacteria from animals in a number of ways, including direct contact and by foodborne transmission. In some cases, zoonotic bacteria can be resistant to antimicrobial drugs, which may complicate treatment of people, should they become ill, or lead to more severe consequences. For these reasons, there is growing interest about how antimicrobial drugs are used in farm environments and the potential impacts of such use on animal-source organisms, particularly those resident in the gastrointestinal tract of animals. This information is and will be critical to meaningful risk assessments and decision making at all levels, from on-farm use of antimicrobial drugs to policy making.

Less than 20 percent of cow-calf operations in the 24 States that participated in the NAHMS Beef 2007–08 study used antibiotics with or without decoquinate/ionophores in the feed of any animals to prevent disease or promote growth. The relatively low use of these products in feed is likely a reflection of the way the animals are managed, i.e., generally without supplemental feeding of mixed concentrates. Grazed or harvested forages account for the majority of feed consumed by cattle in this production setting, and when supplementation is required, protein or energy source is used, but not generally as a mixed diet. Furthermore, the youngest animals on the operations (calves) are generally suckling their dams and are often not provided with supplemental (creep) feed. The next older group, including replacement heifers and other calves, are managed to achieve appropriate growth to facilitate reproduction at the appropriate time in the production calendar, and most of this growth is achieved through forage consumption rather than the consumption of concentrates. Only 4.1 percent of operations incorporated antibiotics with or without decoquinate/ionophores in feed to promote growth in replacement heifers (5.3 percent of operations did so for other calves). Finally, cows have already achieved their full growth potential and are managed to maintain condition and support the growth of their fetuses. Depending on the environmental conditions, some supplementation may be required, but, as stated above, supplementation usually consists of protein supplements and forage with or without some energy supplementation.

Antibiotics are also used to treat various disease conditions on cow-calf operations. Unweaned calves have the highest occurrence of disease, followed by weaned calves, and finally cows. Consequently, a declining proportion of animals are treated with antibiotics with increasing age. Although 68.0 percent of operations had used

oral or injectable antibiotics to treat disease, only 7.2 percent of unweaned calves, 6.0 percent of weaned replacements, and 1.9 percent of cows were treated at least once with oral or injectable antibiotics. The proportion of sick animals treated with an antibiotic depends on the illness; some diseases are not amenable to treatment with antibiotics.

In the Beef 2007–08 study, operation antibiotic use practices were not associated with the likelihood of isolating various enteric bacteria from fecal samples collected on the operations. Because of the relatively low frequency of antibiotic use on the cow-calf operations, such use would have to have profound impacts on the gut flora to be evident in the culture results. In addition, few of the bacteria cultured from feces on the operations were resistant to antibiotics in the susceptibility test panels. Again, given the relatively low frequency of use on these operations, that use would have to have profound and sustained effects on the enteric organisms to be detected by the testing carried out in this study.

Continued efforts by the cattle industry, veterinary profession, and others to encourage judicious use of antibiotics in cow-calf operations and other livestock and poultry production settings is warranted to sustain both animal and public health.

Selected Highlights

This report provides an in-depth look at antimicrobial use practices on U.S. beef cow-calf operations participating in the NAHMS Beef 2007–08 study. The report also describes the occurrence of antimicrobial resistance in *Salmonella, Campylobacter, Enterococcus, Clostridium difficile,* and non-type specific *Escherichia coli* on a subset of operations participating in the study.

Here are a few highlights from the report:

- More than 8 of 10 operations (81.3 percent) did not use antibiotics or decoquinate/ionophores in the feed of any animals to prevent disease or promote growth.

- For weaned calves, 4.1 and 5.3 percent of operations used antibiotics in feed to promote growth in replacement heifers and other weaned calves, respectively. Similarly, 9.8 and 11.9 percent of operations used antibiotics in feed to prevent respiratory disease in replacement heifers and other weaned calves.

- Operations reported that 7.2 percent of unweaned calves, 6.0 percent of weaned replacement heifers not yet calved, and 1.9 percent of cows were treated at least once with oral or injectable antibiotics.

- Use of oral, injectable, or in-feed antibiotics was not associated with recovery of *Salmonella, Campylobacter, Enterococcus,* or non-type specific *E. coli* on the operations participating in testing for these organisms.

- Of the *Salmonella* isolates identified in the Beef 2007–08 study, none was resistant to any of the 15 antimicrobials in the test panel.

- Over half of the *C. jejuni* isolates (56.2 percent) were susceptible to all nine antimicrobials tested. Ciprofloxacin and erythromycin are most often used to treat *Campylobacter* infections in humans, and 6.6 and 0.4 percent, respectively, of *Campylobacter* isolates were resistant to these antimicrobials.

- Vancomycin is commonly used to treat humans with enterococcal infections but has not been used in animal production in the United States. One of the 1,180 *Enterococcus* isolates was resistant to vancomycin, but this finding was determined to be an intrinsic resistance. Synercid® is commonly used to treat vancomycin-resistant infections, and less than 1 percent of the isolates were resistant to Synercid (excluding *E. faecalis* isolates which exhibit intrinsic resistance to Synercid).

- Only 16.6 percent of non-type specific *E. coli* isolates were resistant to any antimicrobials. No resistance to ceftriaxone or ciprofloxacin was observed among *E. coli* isolates.

- When treatment is used for human cases of *C. difficile*-associated disease, vancomycin and metronidazole are the antimicrobials most commonly used. None of the *C. difficile* isolates was resistant to vancomycin and 0.5 percent of isolates were resistant to metronidazole.

Acknowledgments

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We want to thank the NASS enumerators who contacted beef producers and collected data for the Beef 2007-08 study. Their hard work and dedication were invaluable. The roles of the producers, area veterinarians in charge, NAHMS coordinators, veterinary medical officers, and animal health technicians were critical in providing quality data for the Beef 2007–08 reports. Recognition also goes to the personnel at the USDA–APHIS–Veterinary Services' Centers for Epidemiology and Animal Health for their efforts in generating and distributing this report.

Additional biological sampling and testing for the Beef 2007–08 study were afforded by the generous contributions of collaborators, including:

- USDA–ARS
  - –Bovine Functional Genomics Laboratory, Beltsville, MD
  - –Bacterial Epidemiology and Antimicrobial Resistance Research Unit, Athens, GA
  - –Environmental Microbial Safety Laboratory, Beltsville, MD
  - –Virus and Prion Research Unit, Ames, IA
- USDA–APHIS–VS National Veterinary Services Laboratories, Ames, IA
- IDEXX Laboratories, Inc., Westbrook, ME

All participants are to be commended, particularly the producers whose voluntary efforts made the Beef 2007–08 study possible.

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Director
Centers for Epidemiology and Animal Health

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Feedback

Feedback, comments, and suggestions regarding Beef 2007–08 study reports are welcomed. Please forward correspondence via email at: NAHMS@aphis.usda.gov, or you may submit feedback via online survey at: http://nahms.aphis.usda.gov (Click on "FEEDBACK on NAHMS reports.")

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Introduction

The National Animal Health Monitoring System (NAHMS) is a nonregulatory program of the U.S. Department of Agriculture's (USDA) Animal and Plant Health Inspection Service. NAHMS is designed to help meet the Nation's animal health information needs and has collected data on cattle health and management practices on cow-calf operations through two previous studies, the 1992–93 Cow-calf Health and Productivity Audit and Beef '97.

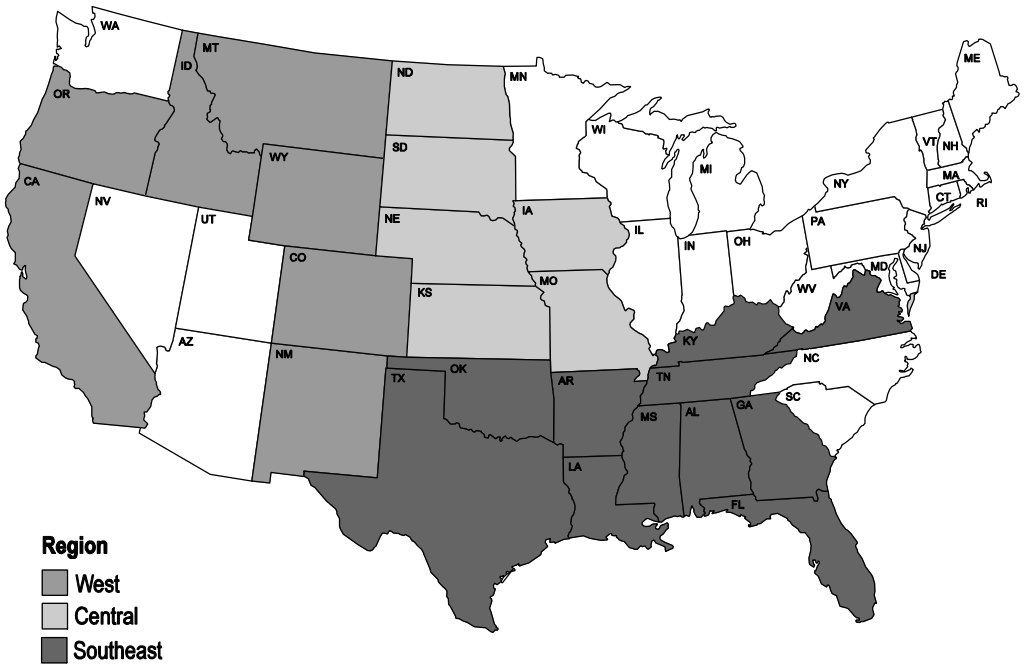
The Beef 2007–08 study was conducted in the 24 States (see map next page)that had the largest beef cow populations and provides participants, stakeholders, and the industry as a whole with valuable information representing 79.6 percent of U.S. cow-calf operations and 87.8 percent of U.S. beef cows. Parts I and II of the study contain information from the 2,159 cow-calf operations that participated in Phase I of the Beef 2007–08 study. Part III provides comparisons among population estimates from all three NAHMS beef studies, Beef 2007–08, Beef '97, and the 1992–93 Cow-calf Health and Productivity Audit.

Of the 2,159 operations participating in Phase I of the Beef 2007–08 study, 1,033 consented to be contacted by a veterinary medical officer regarding participation in Phase II of the study. Of these 1,033 operations, 567 completed the Phase II initial visit questionnaire. Data from the initial visit questionnaire are reported in Part IV of the Beef 2007–08 study. Of the 567 operations that completed the initial visit questionnaire, 470 agreed to continue in Phase II of the study and completed the second visit questionnaire, data from which are reported in Part V of the study.

To assess the prevalence of five types of enteric bacteria (*Salmonella, Campylobacter, Enterococcus, Escherichia coli, and Clostridium difficile*), 173 operations were selected for sample collection from the 567 operations enrolled in Phase II of the study.

Section I of this report provides an overview of antimicrobial drug use and antimicrobial resistance. Section II contains population estimates from management data collected during Phase I and Phase II and provides population inferences on general antimicrobial drug use practices. Section III provides test results from 173 operations on which fecal samples were collected for culturing and bacterial isolate characterization. Data in Section III are not weighted to represent the U.S. beef population. Rather, they describe the management and testing results from 173 operations.

NAHMS Beef 2007-08 Participating States



Terms Used in This Report

Antibiotic: A substance produced by a microorganism that at low concentrations inhibits or kills other microorganisms.

Antimicrobial: Any substance of natural, semisynthetic, or synthetic origin that kills or inhibits the growth of a microorganism but causes little or no damage to the host.

Antimicrobial resistance: A property of microorganisms that confers the ability to inactivate or elude antimicrobials or a mechanism that blocks the inhibitory or killing effects of antimicrobials.

Antimicrobial susceptibility testing: Tests that determine an organism's susceptibility to specific antimicrobials. There are many types of susceptibility tests, but all use inhibition of the organism (rather than killing) as the end point. Qualitative results are usually reported as susceptible, intermediate, or resistant. Quantitative results are usually reported as minimal inhibitory concentrations (MIC) in ìg/mL.

Beef cow: Female bovine that has calved at least once.

Beef heifer: Female bovine that has not yet calved.

Break point: The zones of inhibition or MICs at which an organism is considered to be susceptible, intermediate, or resistant.

Broad spectrum antimicrobial: A type of antimicrobial effective against a large number of bacterial genera; generally describes antimicrobials effective against both gram-positive bacteria and gram-negative bacteria.

Chromosome: A single piece of DNA that contains many genes and is contained within the nucleus of a cell.

Extra-label drug use: Actual use or intended use of a drug, under veterinary direction, in a manner not in accordance with the approved labeling. Includes deviation from the label, including use in nonlisted species, use for nonlisted durations, alternate dosing levels or frequencies, use by routes other than listed, and use of different withdrawal times than listed.

Gene: A segment of DNA that is a unit of heredity. Changes in the DNA sequence constitute mutations, which add to the diversity of a species and could confer antimicrobial resistance.

Gram-negative bacteria: Bacteria decolorized by alcohol in Gram's staining protocol. Compared with Gram-positive bacteria, Gram-negative bacteria have a thinner layer of peptidoglycan in the cell wall.

Gram-positive bacteria: Bacteria that resist decolorization in Gram's staining protocol, thus retaining the crystal violet-iodine complex; a characteristic of bacteria with a thick layer of peptidoglycan and teichoic acid in the cell wall.

Gram's stain: Staining procedure in which bacteria are stained with crystal violet, treated with a solution of iodine, decolorized with alcohol, and counterstained with a contrasting dye. Organisms that retain the stain are deep purple in color and are classified as Gram-positive; organisms that lose crystal violet stain are red in color and classified as Gram-negative.

Herd size: Herd size is based on October 1, 2007, cow inventory. If there were no cows on October 1, 2007, then July 1, 2007, cow inventory was used.

Horizontal gene transfer: The passage of genes between unrelated organisms via mobile genetic elements, such as plasmids.

Intestinal microflora: Microorganisms that maintain a constant presence in the intestine of animals. These organisms help to prevent the overgrowth of pathogenic bacteria.

Microbe: A collective name given to bacteria, viruses, fungi, and parasites.

Minimum inhibitory concentration (MIC): The minimum concentration of an antimicrobial necessary to completely inhibit growth of the organism tested.

Minimum bactericidal concentration (MBC): The minimum concentration of an antimicrobial necessary to kill the organism tested.

Narrow spectrum antimicrobial: A type of antimicrobial effective against a limited number of bacterial genera; an antimicrobial active against specific families of bacteria.

Operation: Premises with at least one beef cow on October 1, 2007, or July 1, 2007.

Operation average: The average value for all operations; a single value for each operation is summed over all operations reporting divided by the number of operations reporting. For example, operation average number of days that antibiotics or decoquinate/ionophores were used (p 23) is calculated by summing reported dollars per head over all operations divided by the number of operations.

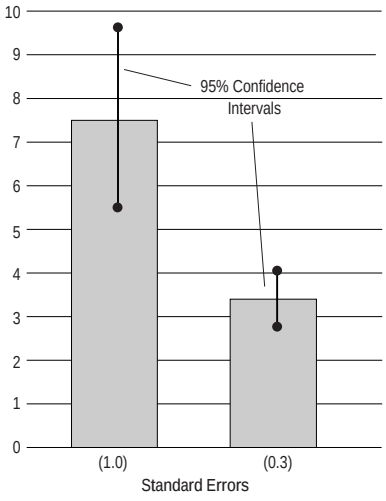
Pathogen: Any disease-producing organism.

Plasmid: A piece of DNA not part of the chromosome that is self-replicating and not essential for bacterial survival. Typically they carry genes that confer some selective advantage to the host bacterium, such as antimicrobial resistance.

Polymerase chain reaction (PCR): The amplification of a specific DNA sequence (or *target sequence*) that is present in a complex mixture. At the end of the amplification, the target sequence can be detected.

Population estimates: The estimates in this report make inference to all of the operations in the target population (see Methodology). Data from the operations responding to the survey are weighted to reflect their probability of selection during sampling and to account for any survey nonresponse.

Examples of a 95% Confidence Interval



Precision of population estimates: Estimates in this report are provided with a measure of precision called the standard error. A 95-percent confidence interval can be created with bounds equal to the estimate plus or minus two standard errors. If the only error is sampling error, the confidence intervals created in this manner will contain the true population mean 95 out of 100 times. In the example to the left, an estimate of 7.5 with a standard error of 1.0 results in limits of 5.5 to 9.5 (two times the standard error above and below the estimate). The second estimate of 3.4 shows a standard error of 0.3 and results in limits of 2.8 and 4.0. Alternatively, the 90-percent confidence interval would be created by multiplying the standard error by 1.65 instead of 2. Most estimates in this report are rounded to the nearest tenth. If rounded to 0, the standard error was reported (0.0). If there were no reports of the event, no standard error was reported (—).

Regions:
West: California, Colorado, Idaho, Montana, New Mexico, Oregon, Wyoming
Central: Iowa, Kansas, Missouri, Nebraska, North Dakota, South Dakota
Southeast: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas, Virginia

Sample profile: Information that describes characteristics of the operations from which Beef 2007–08 data were collected.

Vertical gene transfer: Genes passed from one generation to the next through bacterial replication.

Section I: Antimicrobial Drug Use and Resistance

A. Antimicrobial Drug Use

1. Definitions of antimicrobials

Although the terms *antibiotic* and *antimicrobial* are often used interchangeably, technically they are not the same. An *antibiotic* is a substance produced by a microorganism that at low concentrations inhibits the growth of or kills other microorganisms (Prescott et al., 2000, ch 1). One example of an antibiotic is penicillin, which is produced from *Penicillium* mold and can be used to kill some types of bacteria. An antimicrobial is any substance of natural, semisynthetic, or synthetic origin that inhibits the growth of or kills a microorganism while causing little or no damage to the host. Examples of synthetic antimicrobials include sulfonamides and fluoroquinolones.

Antimicrobials are not limited to antibacterial drugs, as antifungals, antivirals, and antiparasitics are also considered antimicrobial drugs. However, for the remainder of this report, the terms antibiotic and antimicrobial will be used interchangeably and will refer only to antibacterials, unless stated otherwise.

Some drugs, such as ionophores (e.g., monensin), which are used to control coccidiosis in food animals, have activity against protozoa and bacteria, specifically gram-positive bacteria (Prescott et al., 2000, ch 16).

2. How antimicrobials work

Antimicrobials work in a variety of ways and can be administered orally, topically, by infusion, or by injection. Some antimicrobials are *bacteriocidal*; they kill the organism. Others are *bacteriostatic*; they inhibit the growth and replication of the organism, allowing the body's own immune response to clear the infection. There are six main mechanisms by which antimicrobials work to inhibit or kill the bacterium (Prescott, 2000, ch 1, 16; Mascaretti, 2003, ch 6):

1. Inhibition of cell wall synthesis. Antimicrobials such as penicillin, cephalosporins, and avoparcin inhibit synthesis of the bacterial cell wall. The cell wall is an essential component of the organism and if it cannot be synthesized the organism dies.

2. Inhibition of protein synthesis. Tetracyclines, aminoglycosides and chloramphenicol (among others) inhibit protein synthesis within the bacterial cell. Proteins are essential for the organism because the cellular structures and enzymes are generally made of proteins.

3. Inhibition of nucleic acid synthesis. Nucleic acid (DNA and RNA) synthesis is vital for survival of the bacterial cell. Without DNA synthesis the cell cannot replicate, and without RNA synthesis gene expression and protein synthesis are not possible. Quinolones and novobiocin inhibit DNA synthesis, while rifampin blocks RNA synthesis.

4. Inhibition of metabolic pathways. Sulfonamides and trimethoprim block folic acid synthesis, indirectly inhibiting nucleic acid synthesis.

5. DNA destruction. Antimicrobials such as metronidazole and nitrofurans act directly on bacterial DNA by breaking it down, inhibiting survival of the organism.

6. Increase in cell wall permeability. Polypeptides such as polymyxins act by increasing the permeability of the cell membrane. This causes small molecules to leak out of the bacterial cell, leading to cell death.

3. Why antimicrobials are used

Antimicrobials are used to treat or prevent (prophylaxis) disease or disorders caused by bacteria and to improve growth rate and efficiency (National Research Council, 1999, ch 2). One form of prevention is metaphylaxis, which is the timely mass medication of a group of animals to prevent or minimize an expected outbreak of disease.

When using antimicrobials to treat or prevent disease caused by bacteria, selection of the drug depends on (Prescott et al., 2000, ch 5):

1. Susceptibility of the suspected (or laboratory confirmed) pathogen(s)

2. Factors that affect drug concentration at the site of infection

3. Potential drug toxicities

4. Cost of the treatment

5. Regulations of antimicrobial use and withdrawal times

Antimicrobials are also used to increase production performance by increasing the efficiency of the feed consumed by the animal for growth, product output, or by modifying the nutrient composition of an animal product. Almost as soon as antibiotics were introduced, it was recognized that adding low concentrations of antimicrobials to the feed could promote growth. The discovery was made when pigs and poultry were fed fungal waste derived from antibiotic production. The waste was intended as a source of vitamins and protein. Today, it is still uncertain how antimicrobial drugs improve feed efficiency and growth rates. One thought is that low levels of antimicrobials may have an inhibitory or metabolic effect on some gram-positive intestinal microflora.

B. Antimicrobial Resistance

Note: A bacterial strain is defined as resistant to a specific antimicrobial if it continues to grow in the presence of higher concentrations of that drug compared with related susceptible strains that are inhibited (susceptible).

1. Intrinsic versus acquired resistance

Groups of bacteria can be naturally resistant to an antimicrobial if they possess a structural or functional trait that allows for tolerance of a particular antimicrobial or class of antimicrobial. Natural resistance is also known as intrinsic resistance and should be thought of as insensitivity, since it occurs in groups of bacteria that were never sensitive to the drug (Prescott et al., 2000, ch 3; Mascaretti, 2003, ch 5).

Bacteria that are naturally susceptible can become resistant. Resistance can be the result of a specific nonfatal genetic mutation that happens rarely, or can be the result of acquiring genes encoding resistance from another bacterium. *Acquired resistance* is a threat to both animal and human health because the resistance of normally susceptible bacteria, which often occurs by genetic change in a normally susceptible organism, can spread, leading to treatment failure (Prescott et al., 2000, ch 3; Mascaretti, 2003, ch 5). Acquired resistance is associated with only some strains of a bacterial genus or species (unlike intrinsic resistance, which affects an entire bacterial group). When the antimicrobial resistance confers a survival advantage to the organism, the resistance becomes more prevalent. The ability of the bacterium to resist the effects of antimicrobials occurs through one or more of the following mechanisms (Prescott et al, 2000, ch 3):

1. Enzymatic inactivation**.** Some bacteria are able to produce enzymes that inactivate certain antimicrobials. One clinically important enzyme is beta-lactamase, which renders penicillin inactive for inhibiting cell wall synthesis.

2. Decreased cell wall permeability**.** Decreased bacterial cell wall permeability for antimicrobials can occur with a loss or decreased expression of porins, which allow access through the bacterial cell wall. Reduced uptake of antimicrobials is clinically important for beta-lactams and fluoroquinolones against gram-negative bacteria, especially *Pseudomonas aeruginosa* and *Enterobacteriaceae*.

3. Efflux**.** Active drug export, or efflux, is an energy-dependent mechanism used by bacteria to reduce the concentration of the antimicrobial in the cell. Some efflux pumps act on specific drugs (specific-drug-resistance, or SDR pumps), while others are active against multiple drugs (multiple-drug-resistance or MDR pumps). SDR pumps are the most important resistance mechanism against tetracyclines.

4. Alteration in target receptors**.** The drug target receptor can be altered such that the antimicrobial is no longer able to attach and exert its activity on the bacteria. For methicillin-resistant *Staphylococcus aureus* (MRSA), the drug target receptor has been altered.

5. Alteration of metabolic pathways**.** Development of alternative biochemical pathways to bypass the effect of the drug. Some antimicrobials (e.g., sulfonimides) target enzymes used by the bacteria. If the target enzyme mutates or is modified, the bacteria become resistant.

2. Transferrable drug resistance

Plasmids are mobile genetic elements that can transfer antibiotic-resistance genes from one bacterium to another (Prescott et al., 2000, ch 3; Mascaretti, 2003, ch 5). Plasmids are extra-chromosomal circular DNA and are not required for the survival of the bacterial cell. They replicate independently, but synchronously with chromosomal DNA. Plasmids can subsequently be transferred to the cell's offspring (vertical transmission) or neighboring bacterial cells (horizontal transmission).

Plasmids are capable of coding for resistance to one or more different antimicrobials. By treating with any one of the antibiotics for which the plasmid has a resistance gene, maintenance of the entire plasmid is being enhanced. However, the issue of bacterial fitness is very complex. Some research has suggested resistance to a single antimicrobial, such as tetracycline, may have a greater fitness advantage in the presence of tetracycline compared to resistance to multiple antimicrobials.

Transposons, also known as jumping genes, are short sequences of DNA that can contain antimicrobial resistance genes (Prescott et al., 2000, ch 3; Mascaretti, 2003, ch 5). Transposons can move quickly between plasmids within a cell, or between the plasmid and the chromosomal DNA.

Integrons are also mobile genetic elements that are often found on plasmids or transposons (Prescott et al., 2000, ch 3; Mascaretti, 2003, ch 5). Integrons contain collections of genes called gene cassettes. The gene cassettes contain a single antimicrobial resistance gene, but integrons with multiple gene cassettes can develop. Furthermore, genes in the integron can code for resistance to heavy metals and disinfectants. These tightly linked cassettes of resistance genes tend to be transferred or inherited together. Again, use of any of the products for which there are resistance genes in the integron will tend to select for resistance to all of the products. This is called co-selection.

Genes that code for antimicrobial resistance can be transferred horizontally by three different mechanisms. Transduction occurs when the plasmid DNA becomes incorporated into bacteriophage, or bacterial virus, and is transferred to another bacterium (Prescott et al., 2000, ch 3). Bacteriophages are very specific, so this mechanism is of less importance than the others. Transformation is the mechanism by which naked DNA or a DNA fragment is taken up by a cell and incorporated into the recipient's chromosome (Prescott et al., 2000, ch 3). The transfer usually happens between related bacteria and can lead to development of new forms of resistance genes. Transformation is an important source of emergence of antimicrobial resistance.

Conjugation is a common process of gene transfer that involves direct transfer of DNA from one cell to another (Prescott et al., 2000, ch 3). During conjugation, a donor bacterium has direct contact with a recipient cell and transfers copies of plasmid-mediated resistance genes. The donor also retains copies of the plasmid, and the recipient becomes a new potential donor. The transfer of genes can occur between both closely related and unrelated bacteria, such as those of a different genus and species.

3. Assessing antimicrobial susceptibility

There are several *in vitro* methods for testing antimicrobial susceptibility of an organism. All of the methods use inhibition of growth of the bacterium as the endpoint, and test results can be reported either quantitatively or qualitatively. Qualitative results report the organism as susceptible, intermediate, or resistant to the antimicrobial(s) in question. When a laboratory reports that an organism is susceptible, it implies that the recommended dosage of the antimicrobial agent will reach blood or tissue concentrations in the host that are sufficient to inhibit growth of the organism. These reported results are based on predetermined breakpoints that classify the organism as susceptible, intermediate, or resistant to a particular drug. Many times, these breakpoints are determined in human medicine and then carried over into veterinary medicine, and may even be applied to unrelated organisms. The actual organism tested may behave differently than the organism for which the breakpoint was developed. Quantitative results are reported as minimal inhibitory concentrations (MIC) in ìg/mL. The MIC is the minimum concentration of an antimicrobial necessary to completely inhibit growth of the organism tested. The results of quantitative tests are often collapsed and interpreted qualitatively (for example, the MIC below a certain level for a specific drug is deemed "susceptible").

The disk diffusion *test* is based on the diffusion of an antimicrobial agent from a commercially prepared disk that results in a concentration gradient that declines with increasing distance from the disk (Prescott et al., 2000, ch 2). The disk is placed on culture medium that has been seeded with a pure culture of the organism to be tested. A zone of inhibition is formed around the disk, with the border of the zone being the point at which the antimicrobial concentration becomes too low to inhibit growth of the bacterium. The larger the zone of inhibition, the smaller the concentration of that drug needed to inhibit the bacterium. It is important to note that the zone of inhibition for one drug cannot be compared to that of another drug. The zone of inhibition for one drug may be relatively small (compared to other drugs), but is still classified as susceptible. Conversely, another drug may have a relatively large zone of inhibition, but the organism may be considered resistant. The organism can only be classified as susceptible, intermediate, or resistant to a specific drug based upon previously determined breakpoints for that drug. Disk diffusion is the antimicrobial susceptibility test most widely used in veterinary medicine. The disadvantage is that the results can usually only be reported qualitatively, and the specific drug concentrations that are necessary to inhibit growth cannot be determined with this test.

Agar dilution uses agar growth medium that is produced with a known concentration of antimicrobial drug in it (Prescott et al., 2000, ch 2). A series of agar plates with known dilutions are used to determine at what concentration of antimicrobial drug the bacterial growth will be inhibited.
Broth microdilution is also a quantitative test, and is being used more frequently in veterinary laboratories (Prescott et al., 2000, ch 2). The test uses microdilution plates with antimicrobials of known concentration in two-fold dilutions. The isolated bacterium is suspended in broth or saline and diluted to a known concentration and then added to all of the wells. The microdilution plates are then incubated for 16 to 20 hours and the MIC is determined by the lowest concentration of antimicrobial needed to inhibit growth of the bacterium.

DNA-based techniques such as polymerase chain reaction (PCR) are now able to detect resistance genes within bacterial populations (Mascaretti, 2003, ch 5). Since this technique is still being developed and is quite expensive, it is not yet widely used. Microarrays are also being used to screen bacteria for a number of genes, including those coding for antimicrobial resistance.

In vitro tests may not always be able to predict the susceptibility of an organism *in vivo*. *In vivo*, many conditions play a role in whether a strain is considered susceptible or resistant. The location of the infection, the dosage and mode of administration of the drug, tissue distribution of the drug, and the state of the immune system of the individual animal being treated must all be considered. This is why clinical in vivo studies must be combined with in vitro susceptibility tests to predict the efficacy of antimicrobials in the host. After the appropriate antimicrobial has been determined, the ultimate test is the host's response to treatment. If the host is not responding, the course of treatment must be reevaluated.

4. Why antimicrobial resistance is a concern

The short generation times of bacterial organisms, combined with their ability to mutate and transfer genetics, can lead to rapid production of resistant populations. Until recently, antimicrobial resistance could generally be overcome with the development of new antimicrobials. Unfortunately, the development of new antimicrobials has slowed due to the tremendous expense of research, development, and long-term clinical trials.

In 1998, the American Veterinary Medical Association (AVMA) approved the Judicious Use of Antimicrobial Therapy policy (AVMA, 2008). The goal of this policy is to preserve the therapeutic efficacy of antimicrobials and to ensure the current and future availability of veterinary antimicrobials. The AVMA recognized the need for improved monitoring and feedback systems for antimicrobial use and resistance patterns as well as more research to improve scientifically based therapeutic practices. Many of the veterinary species specialty groups have also developed judicious use guidelines and distributed them to their members. For example, "A Beef Producers Guide for Judicious Use of Antimicrobials in Cattle" provides the following guidelines:*

1. Prevent Problems: Emphasize appropriate husbandry and hygiene, routine health examinations, and vaccinations.

2. Select and Use Antibiotics Carefully: Consult with the herd veterinarian on the selection and use of antibiotics. Have a valid reason to use an antibiotic. Therapeutic alternatives should be considered prior to using antimicrobial therapy.

3. Avoid Using Antibiotics Important In Human Medicine As First Line Therapy: Avoid using as the first antibiotic those medications that are important to treating strategic human or animal infections.

4. Use the Laboratory to Help You Select Antibiotics: Cultures and susceptibility test results should be used to aid in the selection of antimicrobials, whenever possible.

5. Combination Antibiotic Therapy Is Discouraged Unless There Is Clear Evidence The Specific Practice Is Beneficial: select and dose an antibiotic to affect a cure.

6. Avoid Inappropriate Antibiotic Use: Confine therapeutic antimicrobial use to proven clinical indications, avoiding inappropriate uses such as for viral infections without bacterial complication.

7. Treatment Programs Should Reflect Best Use Principles: Regimens for therapeutic antimicrobial use should be optimized using current pharmacological information and principles.

8. Treat the Fewest Number of Animals Possible: Limit antibiotic use to sick or at-risk animals.

* NCBA BQA Train the Trainer Manual. Available at http://www.bqa.org.

9. Treat for the Recommended Time Period: To minimize the potential for bacteria to become resistant to antimicrobials.

10. Avoid Environmental Contamination with Antibiotics: Steps should be taken to minimize antimicrobials reaching the environment through spillage, contaminated ground runoff or aerosolization.

11. Keep Records of Antibiotic Use: Accurate records of treatment and outcome should be used to evaluate therapeutic regimens and always follow proper withdrawal times.

12. Follow Label Directions: Follow label instructions and never use antibiotics other than as labeled without a valid veterinary prescription.

13. Extra-label Antibiotic Use Must follow FDA Regulations: Prescriptions, including extra-label use of medications must meet the Animal Medicinal Drug Use Clarification Act (AMDUCA) amendments to the Food, Drug, and Cosmetic Act and its regulations. This includes having a Veterinary/Client/Patient Relationship.

14. Subtherapeutic Antibiotic Use Is Discouraged: Antibiotic use should be limited to prevent or control disease and should not be used if the principle intent is to improve performance.

Antibiotic use guidelines

1. Strictly follow all recommendations and guidelines from herd veterinarian for selection of products.

2. Follow label directions for use of product. Use product at recommended dosage for required time period. Treatment regimens must comply with label directions unless otherwise prescribed by a veterinarian. If drugs are to be used in an extra-label manner, that must be done under the prescription or direct supervision of a licensed veterinarian. All cattle treated in an extra-label manner must comply with prescribed withdrawal times, which have been set by a herd veterinarian under the guidelines of a Veterinarian-Client-Patient Relationship (VCPR).*

The BQA program does not support/recommend extra-label drug use (ELDU) for injectable aminoglycosides (such as neomycin, gentamicin or kanamycin) because of the potential violative residues related to extremely long withdrawal times. Some studies have shown withdrawal times on these types of products could be as long as 18 months.

3. Accurately calculate dose requirements based on the animal's weight and the specific health problem being treated. Providing the same drug simultaneously by injection, feed or water may result in overdosing and, thereby, create a residue problem.

*A valid VCPR is defined as one in which:
1. A veterinarian has assumed the responsibility for making medical judgments regarding the health of (an) animal(s) and the need for medical treatment, and the client (the owner of the animal or animals or other caretaker) has agreed to follow the instructions of the veterinarian;
2. There is sufficient knowledge of the animal(s) by the veterinarian to initiate at least a general or preliminary diagnosis of the medical condition of the animal(s); and
3. The practicing veterinarian is readily available for follow-up in case of adverse reactions or failure of the regimen of therapy.
Such a relationship can exist only when the veterinarian has recently seen and is personally acquainted with the keeping and care of the animal(s) by virtue of examination of the animal(s), and/or by medically appropriate and timely visits to the premises where the animal(s) are kept.

4. When administering injectable products, follow the Best Management Practices for Injections.

5. Never administer more than 10 cc per IM injection site. Exceeding this amount will increase tissue damage, alter withdrawal time and may require testing before cattle are marketed for consumption.

6. Do not mix products prior to administration. This practice of using "Bloody Mary" mixes is compounding use and will result in undetermined withdrawal periods.

7. All animals treated for problems unique to the individual animal should be recorded by the animal's ID, treatment date, drug and dose administered product serial/lot number, approximate weight of animal, route and location of administration, and the earliest date the animal would clear the prescribed or labeled withdrawal period. You can record treatments either by individually identifying each animal in your herd and/or individually identifying each animal when or if they are treated. The ID number should be unique to that animal and tie it to the group from which it came.

8. A special note for producers who do not individually identify animals: Identifying each animal individually is not required to participate in this program. Cattle can be identified by group. However, if treated cattle are not individually identified, then the entire group must be managed together until the appropriate withdrawal times have elapsed for every animal in the group. The withdrawal time applies to the entire group of animals.

For example, let's say several calves develop scours and numerous calves are treated within a 10-day period. The entire group of calves would receive a withdrawal date based on the last date of administration of the product (to any individual animal) with the longest withdrawal period. The complete history of product use should be available for transfer when the group of cattle is sold or moved to the next production unit within an operation.

Otherwise, the buyer (or the foreman of the other unit) will not be aware of when those calves can safely enter the marketing chain. For example, when a stocker operator culls his nonperforming steers any time during the course of a grazing period, those animals could potentially be sent to a packer. If the stocker operator is unaware that the prior owner treated the animal with an antibiotic whose withdrawal time has not expired, he might have unknowingly contributed to a violative residue problem.

9. All animals treated as part of a group will be identified by group or lot with treatment information recorded. Records should include the animal lot or group identification, processing/treatment date, product serial/lot number, product and dose administered, route and location of administration, name of person who administered it and withdrawal information. Recording animals under this system assumes that every animal in the lot or group received the treatment.

10. All cattle marketed from the operation can potentially go directly to harvest. Therefore, records for any cattle to be marketed should be checked by personnel to ensure that treated animals will meet or exceed label withdrawal times for all products administered. A release slip should be signed and dated by the person who checks records prior to shipping cattle from the operation. The examination should include processing records, feeding records, treatment records and all other records that may apply.

11. Extended withdrawal times should be expected for emaciated or severely debilitated animals. All cattle sold that are not typical of the herd (medicated market cows/bulls and realizer cattle) may be subject to verification of drug withdrawal. (Realizers are animals with a health problem that get culled because they never recover.) Should there be any question about withdrawal period, the veterinarian will evaluate the treatment history against information provided by the Food Animal Residue Avoidance Databank and the animal may have to pass a residue screening test, such as the Live Animal Swab Test (LAST), which tests for antibiotic residues. Residue screening will be performed by qualified personnel under the supervision of a veterinarian. The results will determine whether the animals can be released for shipment, but cannot be used to shorten the labeled withdrawal time. Attempting to salvage sick animals by treatment and prompt harvest requires an accurate diagnosis and careful selection of drugs.

12. Make sure that all employees are aware of the proper use and administration of antibiotics and withdrawal times, and they have the ability to check appropriate withdrawal restrictions before moving cattle to market. For example, provide employees with charts or software to help them track withdrawal dates.

5. Foodborne illness

Foodborne illnesses are defined as diseases caused by agents that enter the body through the ingestion of food. It has been reported that up to 30 percent of the human population in industrialized nations suffers from foodborne illness each year. It is estimated that each year in the United States there are 47.8 million cases of foodborne illness, resulting in 127,839 hospitalizations and 3,037 deaths (Scallan, 2011a, 2011b). Norovirus, nontyphoidal *Salmonella* spp., *Clostridium perfringins*, *Campylobacter* spp., and *Staphylococcus aureus* account for over 90 percent of domestically acquired foodborne illness cases in the United States (Scallan, 2011b). The health-related cost of foodborne illness in the United States is estimated to be $152 billion annually (Scharff, 2010).

Salmonella, Campylobacter, and *E. coli* are three of the bacterial organisms that most commonly cause foodborne illness. If bacteria with resistance genes are present in farm animals, it is possible these may get transferred to humans through food consumption (by meat contaminated during slaughter) or direct contact. If organisms can survive and be transferred from farm animals to the human gastrointestinal tract, the resistance genes contained by the organism can also be transferred.

6. Complexity of antimicrobial resistance

Antimicrobial resistance is a complex issue. There are many factors that can affect the frequency of occurrence of bacterial organisms with resistance determinants among bacterial populations. These factors include exposure to antimicrobial drugs and exposure to metals, disinfectants, and other environmental conditions that affect the fitness of certain strains of bacteria that may also possess resistance genes. Furthermore, bacterial populations resistant to antimicrobial drugs may reside in a number of different subpopulations. Bacteria can be transferred among these subpopulations through any number of routes, eventually ending up in other subpopulations either transiently or established for the long term.

Section II: Population Estimates*

Antimicrobial Drug Use

1. Antibiotics and decoquinate/ ionophores in feed [1]

Antibiotics may be incorporated into cattle feed at rates specified by the U.S. Food and Drug Administration to control, prevent, or treat disease. These specified rates are determined during the approval process, prior to marketing the antibiotic. Subsequently, feed mills and producers are required to use the products as indicated on their labels.

Decoquinate is used in feed to prevent or treat coccidiosis. Ionophores such as monensin and lasalocid are used in feed to prevent coccidiosis and improve feed efficiency.[1] Again, these products can be used only according to the specifications on the products' labels.

Overall, the majority of operations (81.3 percent) did not use antibiotics or decoquinate/ionophores in cattle feed to prevent disease or promote growth. A higher percentage of operations with 1 to 49 beef cows (86.2 percent) did not use either type of additive in feed compared with operations with 200 or more beef cows (57.8 percent).

a. Percentage of operations that used the following additives in cattle feed to prevent disease and/or promote growth, by herd size

	Percent Operations									
	Herd Size (number of beef cows)								All operations and all classes of cattle	
	1–49		50–99		100–199		200 or more			
Additives in feed used	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error
Antibiotics with or without decoquinate or ionophores	11.9	(2.7)	22.1	(4.7)	24.9	(4.5)	31.6	(4.7)	15.8	(2.1)
Decoquinate/ ionophores only	1.9	(1.0)	4.4	(1.9)	3.5	(1.8)	10.6	(2.9)	2.9	(0.8)
Neither	86.2	(2.8)	73.5	(5.0)	71.6	(4.8)	57.8	(5.0)	81.3	(2.2)
Total	100.0		100.0		100.0		100.0		100.0	

*Note: Estimates in Section II are based on producer responses to questionnaires completed during both Phase I and Phase II of the study. These responses were weighted to reflect the inference population for which they were selected. Additional details are presented in Section IV.

[1]In collecting the data for this section, producers were asked about their use of "antibiotics in feed to prevent disease and/or promote growth." Data collectors were instructed to include products such as decoquinate or ionophores under the general term "antibiotics" for this question. However, it is possible that some producers may not have reported use of decoquinate or ionophores, even though they were used, because many do not consider these products to be true antibiotics. (Ionophores are antibiotics; however, decoquinate is not an antibiotic but was considered an antibiotic for the purpose of this question.)

In the West region, 94.6 percent of operations did not use antibiotics or decoquinate/ionophores in cattle feed to treat disease or promote growth. Use of one or the other product was most common in the Central region, where 34.7 percent of operations used one or both types.

b. Percentage of operations that used the following additives in cattle feed to prevent disease and/or promote growth, by region

	Percent Operations					
	Region					
	West		Central		Southeast	
Additives in feed used	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error
Antibiotics with or without decoquinate or ionophores	4.1	(1.4)	28.0	(4.2)	12.8	(2.6)
Decoquinate/ ionophores only	1.3	(0.6)	6.7	(2.3)	1.7	(0.8)
Neither	94.6	(1.6)	65.3	(4.5)	85.5	(2.7)
Total	100.0		100.0		100.0	

Photograph courtesy of Anson Eaglin.

Producers were asked whether antibiotics with or without decoquinate/ionophores were used in feed to prevent respiratory diseases, promote growth, or for other reasons. Overall, 10.7, 10.7, and 13.0 percent of operations used antibiotics in feed for any reason in preweaned calves, weaned replacement heifers, and other weaned calves, respectively. For weaned calves, 4.1 percent and 5.3 percent of all operations used antibiotics in feed to promote growth in replacement heifers and other weaned calves, respectively.

c. Percentage of operations that used antibiotics with or without decoquinate/ionophores or that used decoquinate/ionophores only in the feed of the following cattle classes, by primary purpose of use and by herd size

Percent Operations

Herd Size (number of beef cows)

	1-49		50-99		100-199		200 or more		All operations	
Primary purpose	**Pct.**	**Std. error**	**Pct.**	**Std. error**	**Pct.**	**Std. error**	**Pct.**	**Std. error**	**Pct.**	**Std. error**
Preweaned calves										
Prevent respiratory disease	9.1	(2.4)	10.1	(3.2)	8.5	(3.0)	5.3	(2.0)	9.0	(1.7)
Other	1.4	(0.9)	5.1	(2.3)	4.5	(1.9)	5.0	(1.7)	2.5	(0.7)
Any	10.0	(2.4)	14.0	(3.8)	10.8	(3.2)	9.1	(2.5)	10.7	(1.8)
Replacement heifers weaned but not yet calved										
Prevent respiratory disease	7.7	(2.1)	12.4	(3.8)	15.5	(3.5)	19.8	(4.4)	9.8	(1.6)
Promote growth	2.8	(1.4)	5.3	(2.4)	5.6	(1.8)	15.8	(4.0)	4.1	(1.1)
Other	0.0	(0.0)	0.1	(0.1)	2.7	(1.4)	3.6	(1.1)	0.5	(0.1)
Any	7.7	(2.1)	13.9	(3.9)	17.5	(3.6)	27.6	(4.6)	10.7	(1.6)
Other calves weaned but not yet shipped for feeding or sold as breeding stock										
Prevent respiratory disease	7.7	(2.0)	21.5	(4.7)	16.9	(3.7)	29.5	(4.8)	11.9	(1.7)
Promote growth	3.2	(1.5)	7.3	(2.7)	8.3	(2.7)	21.3	(4.5)	5.3	(1.2)
Other	0.0	(0.0)	1.5	(1.0)	1.4	(1.4)	5.6	(1.6)	0.7	(0.2)
Any	7.9	(2.0)	23.6	(4.8)	19.3	(4.0)	36.0	(4.9)	13.0	(1.7)

Of the 15.8 percent of operations that used antibiotics with or without decoquinate/ionophores in cattle feed to prevent disease and/or promote growth (see Section II, table 1.a.), 50.9 percent used them in the feed of any preweaned calves to prevent respiratory disease. A higher percentage of small operations with 1 to 49 beef cows used antibiotics in the feed of preweaned calves to prevent respiratory disease compared with operations with 200 or more beef cows. Nearly two-thirds of operations (61.0 percent) used antibiotics in the feed of any replacement heifers weaned but not yet calved to prevent respiratory disease. For other weaned calves not yet shipped, nearly three of four operations (73.5 percent) used antibiotics in feed to prevent respiratory disease.

d. For the 15.8 percent of operations that used antibiotics with or without decoquinate/ionophores in cattle feed, percentage of operations that used antibiotics for the following cattle classes, by primary purpose of use and by herd size

	Percent Operations*									
	Herd Size (number of beef cows)									
	1-49		50-99		100-199		200 or more		All operations	
Primary purpose	**Pct.**	**Std. error**	**Pct.**	**Std. error**	**Pct.**	**Std. error**	**Pct.**	**Std. error**	**Pct.**	**Std. error**
Preweaned calves										
Prevent respiratory disease	69.4	(10.6)	37.5	(11.2)	34.0	(9.4)	11.7	(4.7)	50.9	(6.8)
Other	7.3	(5.3)	4.6	(3.2)	10.0	(5.5)	8.3	(4.2)	7.2	(3.0)
Any	71.9	(10.5)	40.0	(11.3)	35.1	(9.3)	18.7	(6.1)	53.7	(6.7)
Replacement heifers weaned but not yet calved										
Prevent respiratory disease	65.8	(11.5)	56.2	(11.5)	59.0	(9.2)	52.5	(9.1)	61.0	(6.6)
Promote growth	21.2	(10.8)	12.3	(6.3)	6.5	(3.7)	16.7	(8.6)	16.3	(5.8)
Other	0.0	(—)	0.7	(0.7)	9.4	(5.3)	4.9	(2.3)	2.1	(0.9)
Any	65.8	(11.5)	59.4	(11.4)	62.1	(9.2)	55.5	(8.9)	62.6	(6.5)
Other calves weaned but not yet shipped for feeding or sold as breeding stock										
Prevent respiratory disease	65.6	(11.7)	92.8	(4.7)	61.4	(9.4)	83.5	(5.8)	73.5	(6.4)
Promote growth	22.9	(10.9)	17.0	(7.4)	13.9	(6.9)	34.5	(9.9)	21.4	(6.0)
Other	0.0	(—)	0.0	(—)	5.6	(5.4)	6.8	(2.9)	1.6	(0.9)
Any	65.6	(11.7)	95.3	(4.0)	65.0	(9.2)	85.1	(5.6)	74.8	(6.4)

*Note that due to the small number of reports estimates are associated with large standard errors.

As shown in Section II, table 1.a., only 2.9 percent of operations used only decoquinate/ionophores as a feed additive to prevent disease and/or promote growth. Of these operations, 27.9, 19.5, and 28.6 percent used decoquinate/ionophores to prevent respiratory disease in preweaned calves, weaned replacement heifers, and other weaned calves, respectively.

e. For the 2.9 percent of operations that used only decoquinate/ionophores in cattle feed, percentage of operations that used decoquinate/ionophores for the following cattle classes, by primary purpose of use and by herd size

Percent Operations

Herd Size (number of beef cows)

	1-49		50-99		100-199		200 or more		All operations	
Primary purpose	**Pct.**	**Std. error**	**Pct.**	**Std. error**	**Pct.**	**Std. error**	**Pct.**	**Std. error**	**Pct.**	**Std. error**
Preweaned calves										
Prevent respiratory disease	32.7	(25.7)	41.8	(23.2)	0.0	(—)	14.8	(11.1)	27.9	(13.6)
Other	29.6	(24.4)	52.1	(22.9)	12.3	(12.3)	14.6	(7.1)	30.3	(12.7)
Any	62.3	(24.0)	76.8	(19.8)	12.3	(12.3)	29.4	(12.3)	54.0	(13.3)
Replacement heifers weaned but not yet calved										
Prevent respiratory disease	24.6	(21.7)	0.0	(—)	23.6	(21.1)	29.9	(15.4)	19.5	(10.9)
Promote growth	24.6	(21.7)	16.7	(15.7)	36.0	(23.6)	72.1	(10.8)	32.9	(11.9)
Other	0.0	(—)	0.0	(—)	0.0	(—)	16.5	(8.2)	3.1	(1.7)
Any	24.6	(21.7)	16.7	(15.7)	36.0	(23.6)	83.9	(8.6)	35.2	(12.1)
Other calves weaned but not yet shipped for feeding or sold as breeding stock										
Prevent respiratory disease	24.6	(21.7)	23.2	(19.8)	54.0	(26.2)	29.9	(15.4)	28.6	(11.9)
Promote growth	37.6	(24.0)	39.9	(22.2)	69.6	(24.8)	65.7	(13.2)	47.1	(13.5)
Other	0.0	(—)	18.3	(17.0)	0.0	(—)	23.4	(10.4)	8.9	(5.1)
Any	37.6	(24.0)	58.2	(23.2)	100.0	(—)	76.8	(11.6)	57.0	(14.3)

Across all cattle classes, nearly 9 of 10 operations did not use any of the following primary feed additives for any purpose. For both preweaned calves and replacement heifers, 87.3 percent of operations did not feed any feed additives for any purpose. Similarly, 87.0 percent did not use feed additives for other calves for any purpose.

f. Percentage of operations in which additives were used in the feed of the following cattle classes, by primary purpose of use and by primary additive

	Percent Operations												
	Primary Additive												
	Tetracyclines		Peptides		Combinations/ other		Decoquinates/ ionophores		Fed but unknown type		None fed		
Primary purpose	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Total
Preweaned calves													
Prevent respiratory disease	6.5	(1.4)	0.7	(0.7)	0.7	(0.5)	1.0	(0.5)	0.1	(0.1)	91.0	(1.7)	100.0
Other	0.8	(0.4)	0.0	(—)	0.2	(0.2)	1.4	(0.5)	0.1	(0.1)	97.5	(0.7)	100.0
Any	6.7	(1.4)	0.7	(0.7)	0.9	(0.5)	2.2	(0.7)	0.1	(0.1)	89.3	(1.8)	
Replacement heifers weaned but not yet calved													
Prevent respiratory disease	7.6	(1.4)	0.0	(—)	0.9	(0.3)	0.6	(0.4)	0.7	(0.7)	90.2	(1.6)	100.0
Promote growth	1.7	(0.7)	0.0	(—)	0.0	(0.0)	1.7	(0.5)	0.8	(0.7)	95.8	(1.1)	100.0
Other	0.3	(0.1)	0.0	(—)	0.0	(—)	0.1	(0.1)	0.1	(0.1)	99.5	(0.1)	100.0
Any	7.7	(1.4)	0.0	(—)	0.9	(0.3)	1.7	(0.5)	0.8	(0.7)	89.3	(1.8)	
Other calves weaned but not yet shipped for feeding or sold as breeding stock													
Prevent respiratory disease	8.7	(1.4)	0.0	(—)	1.6	(0.5)	0.8	(0.4)	0.8	(0.7)	88.1	(1.7)	100.0
Promote growth	2.1	(0.7)	0.0	(—)	0.4	(0.2)	2.1	(0.6)	0.7	(0.7)	94.7	(1.2)	100.0
Other	0.1	(0.0)	0.1	(0.1)	0.0	(0.0)	0.4	(0.2)	0.0	(0.0)	99.4	(0.2)	100.0
Any	8.8	(1.4)	0.1	(0.1)	1.7	(0.5)	2.5	(0.6)	0.8	(0.7)	87.0	(1.7)	

The 9.0 percent of operations that used antibiotics in the feed of preweaned calves to prevent respiratory disease (see Section II, table 1.c.) included the antibiotics in the feed for an average of 127.4 days. A similar average duration (119.4 days) was used among the 9.8 percent of operations that included antibiotics in the feed of weaned replacement heifers to prevent respiratory disease. For prevention of respiratory disease in other weaned calves, the average duration of inclusion for the 11.9 percent of operations using this practice was 92.5 days. While there are numerical differences in the duration of inclusion of antibiotics in the feed for different purposes by type of cattle, these differences are not significantly different based on statistical analysis.

g. For operations that used antibiotics with or without decoquinate/ionophores or only decoquinate/ionophores in cattle feed, operation average number of days that antibiotics or decoquinate/ionophores were used for the following cattle classes, by primary purpose of use

	Operation Average Number of Days[1]			
	Antibiotics[2]		Decoquinate/ionophores only	
Primary purpose	**Number**	**Std. error**	**Number**	**Std. error**
Preweaned calves				
Prevent respiratory disease	127.4	(29.8)	125.9	(48.6)
Other	106.1	(30.6)	102.5	(9.8)
Replacement heifers weaned but not yet calved				
Prevent respiratory disease	119.4	(29.3)	146.5	(98.9)
Promote growth	76.1	(32.0)	140.8	(32.0)
Other	28.2	(15.6)	86.0	(32.4)
Other calves weaned but not yet shipped for feeding or sold as breeding stock				
Prevent respiratory disease	92.5	(24.2)	109.1	(60.8)
Promote growth	53.6	(15.0)	172.2	(45.2)
Other	62.4	(17.1)	140.9	(67.7)

[1]Note: Due to the relatively low number of operations reporting the use of these practices and the wide variation in the reported values for duration of inclusion in feed, the estimates in this table are associated with large standard error values. The effect is a lack of precision for the estimates that are reported here.
[2]With or without decoquinate.

The 18.7 percent of operations that used antibiotics with or without decoquinate/ionophores or only decoquinate/ionophores in feed to prevent disease and/or promote growth (see Section II, table 1.a.) reported a variety of influences when deciding which additives to use. Similar percentages of operations cited local veterinary practitioners, suppliers other than veterinarians, trade journals, and other producers as primary influences on additive use for prevention of respiratory disease or growth promotion. Few operations reported that consulting or second-opinion veterinarian was the primary influence on additive choice. This finding is likely due to the relatively low use of consulting veterinarians on beef cow-calf operations compared with the use of local private veterinary practitioners.

h. For the 18.7 percent of operations that used antibiotics with or without decoquinate/ionophores or only decoquinate/ionophores in feed to prevent disease and/or promote growth, percentage of operations that used them in the following cattle classes, by primary purpose of use and by primary influence on decision about which to use

	Percent Operations																				
	Primary Influence																				
	Trade journals		Other producers		Local veterinary practitioner		Consulting or second-opinion veterinarian		Supplier of antibiotics other than veterinarian		Other		No other influence								
Primary purpose	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error							Total
Preweaned calves																					
Prevent respiratory disease	9.8	(6.0)	14.6	(6.7)	32.1	(9.9)	0.1	(0.1)	37.2	(9.6)	0.0	(—)	6.2	(3.1)							100.0
Other	0.0	(—)	0.0	(—)	12.6	(5.8)	0.0	(—)	66.2	(13.7)	0.0	(—)	21.2	(13.6)							100.0
Replacement heifers weaned but not yet calved																					
Prevent respiratory disease	13.1	(6.2)	11.2	(5.6)	34.5	(8.4)	1.4	(0.9)	21.9	(5.9)	9.0	(5.4)	8.9	(3.6)							100.0
Promote growth	10.3	(9.9)	2.9	(1.8)	27.9	(14.2)	2.3	(2.0)	31.6	(10.4)	18.7	(11.9)	6.3	(4.0)							100.0
Other	0.0	(—)	0.0	(—)	43.4	(15.0)	0.0	(—)	36.8	(17.9)	9.5	(6.9)	10.3	(6.7)							100.0
Other calves weaned but not yet shipped for feeding or sold as breeding stock																					
Prevent respiratory disease	8.4	(4.4)	12.0	(5.1)	32.0	(7.3)	2.3	(1.3)	25.1	(5.5)	7.5	(4.5)	12.7	(3.6)							100.0
Promote growth	9.3	(7.8)	4.2	(2.6)	33.7	(11.5)	4.2	(2.9)	26.8	(8.2)	14.3	(9.4)	7.5	(3.6)							100.0
Other	0.0	(—)	1.6	(1.7)	38.9	(16.7)	0.0	(—)	48.0	(17.3)	1.7	(1.8)	9.8	(5.8)							100.0

Of the 18.7 percent of operations that used antibiotics with or without decoquinate/ ionophores or only decoquinate/ ionophores in feed to prevent disease and/or promote growth (see Section II, table 1.a.), the highest percentage used tetracyclines as the primary additive to prevent respiratory disease across all cattle classes. Similar percentages of operations used decoquinate/ionophores or tetracyclines as the primary additives used for growth promotion.

i. For the 18.7 percent of operations that used antibiotics with or without decoquinate/ionophores or only decoquinate/ionophores in feed to prevent disease and/or promote growth, percentage of operations that used them in the following cattle classes, by primary purpose of use and by primary additive

	Percent Operations										
	Primary Additive										
	Tetracyclines		Peptides		Combina-tions/ other		Decoqui-nates/ ionophores		Fed but unknown type		
Primary purpose	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Total
Preweaned calves											
Prevent respiratory disease	72.3	(9.4)	8.0	(7.5)	7.9	(5.5)	10.9	(5.5)	0.9	(0.8)	100.0
Other	33.9	(13.9)	0.0	(—)	9.0	(8.0)	54.6	(14.5)	2.5	(2.5)	100.0
Replacement heifers weaned but not yet calved											
Prevent respiratory disease	77.0	(7.7)	0.0	(—)	9.6	(3.5)	5.8	(3.5)	7.6	(7.1)	100.0
Promote growth	40.5	(13.0)	0.0	(—)	0.3	(0.3)	40.2	(12.1)	19.0	(15.1)	100.0
Other	55.6	(15.4)	0.0	(—)	0.0	(—)	29.4	(12.3)	15.0	(10.5)	100.0
Other calves weaned but not yet shipped for feeding or sold as breeding stock											
Prevent respiratory disease	72.9	(6.8)	0.0	(—)	13.4	(3.9)	7.0	(3.3)	6.7	(5.9)	100.0
Promote growth	39.7	(10.7)	0.0	(—)	7.1	(3.9)	39.2	(10.1)	14.0	(12.3)	100.0
Other	8.6	(5.4)	21.1	(16.4)	3.3	(3.3)	63.5	(16.5)	3.5	(3.5)	100.0

2. Use of oral or injectable antibiotics for disease treatment

Antibiotics are used to both prevent and treat disease. Antibiotics used to treat disease can be administered orally (in feed, water, or directly to individual animals, e.g., boluses) or injected.

More than two of three operations (68.0 percent) used oral or injectable antibiotics to treat disease in any cattle or calves. Operations with 1 to 49 beef cows were less likely to use oral or injectable antibiotics to treat any cattle or calves than operations with 50 or more beef cows. This difference could be a reflection of the decreased likelihood of disease occurrence when fewer animals are present, thereby decreasing the indication for antibiotic use for treatment.

a. Percentage of operations that used oral or injectable antibiotics to treat disease, by herd size

Percent Operations

Herd Size (number of beef cows)

1–49		50–99		100–199		200 or more		All operations	
Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error
58.2	(4.4)	89.1	(3.6)	90.8	(3.0)	92.4	(3.2)	68.0	(3.2)

The Southeast region had a lower percentage of operations that used oral or injectable antibiotics to treat disease compared with the Central region.

b. Percentage of operations that used oral or injectable antibiotics to treat disease, by region

Percent Operations

Region

West		Central		Southeast	
Percent	Std. error	Percent	Std. error	Percent	Std. error
76.3	(5.0)	86.1	(3.9)	60.2	(4.5)

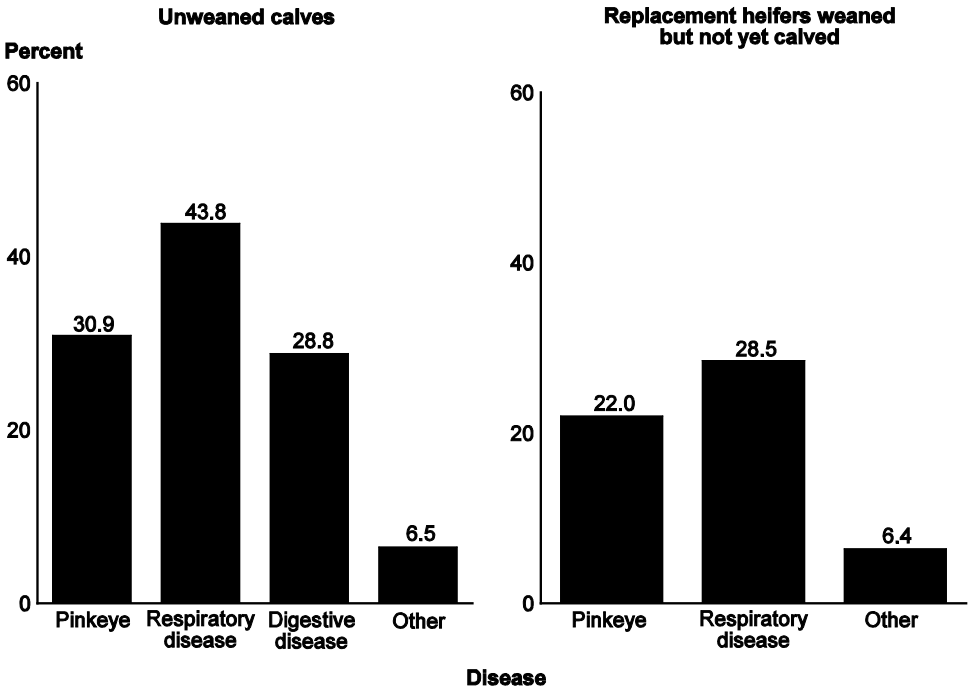
In unweaned calves, a higher percentage of operations with 50 or more beef cows than operations with 1 to 49 beef cows used antibiotics to treat pinkeye and respiratory and digestive diseases in unweaned calves.

Similarly, operations with 50 or more beef cows were more likely than operations with 1 to 49 beef cows to use oral or injectable antibiotics to treat replacement heifers for respiratory disease.

c. Percentage of operations that treated unweaned calves and replacement heifers weaned but not yet calved with oral or injectable antibiotics, by disease treated and by herd size

	Percent Operations									
	Herd Size (number of beef cows)									
	1-49		**50-99**		**100-199**		**200 or more**		**All operations**	
Disease	**Pct.**	**Std. error**	**Pct.**	**Std. error**	**Pct.**	**Std. error**	**Pct.**	**Std. error**	**Pct.**	**Std. error**
Unweaned calves										
Pinkeye	24.4	(3.7)	45.5	(6.2)	43.8	(5.8)	49.0	(5.4)	30.9	(2.9)
Respiratory disease	31.6	(4.0)	69.2	(5.8)	70.9	(6.1)	79.6	(4.2)	43.8	(3.2)
Digestive disease	20.8	(3.7)	46.5	(6.3)	41.4	(5.6)	57.8	(5.4)	28.8	(2.8)
Other	5.2	(1.7)	10.6	(3.4)	5.5	(2.0)	13.1	(3.6)	6.5	(1.3)
Replacement heifers weaned but not yet calved										
Pinkeye	17.6	(3.2)	28.9	(5.4)	33.9	(5.4)	37.6	(5.3)	22.0	(2.5)
Respiratory disease	21.4	(3.5)	42.0	(6.4)	41.5	(5.7)	58.1	(5.2)	28.5	(2.8)
Other	4.0	(1.5)	11.5	(4.1)	11.0	(3.0)	14.6	(3.0)	6.4	(1.3)

Percentage of operations that treated unweaned calves and replacement heifers with oral or injectable antibiotics, by disease treated



A higher percentage of operations in the Central region used antibiotics to treat respiratory disease in unweaned calves compared with operations in the other two regions.

d. Percentage of operations that treated unweaned calves and replacement heifers weaned but not yet calved with oral or injectable antibiotics, by disease treated and by region

	Percent Operations					
	Region					
	West		Central		Southeast	
Disease	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error
Unweaned calves						
Pinkeye	30.2	(6.3)	44.7	(5.0)	25.8	(3.7)
Respiratory disease	39.4	(6.5)	66.9	(5.0)	35.8	(4.2)
Digestive disease	33.4	(6.1)	47.3	(5.0)	21.3	(3.6)
Other	10.3	(4.3)	8.7	(2.3)	5.1	(1.7)
Replacement heifers weaned but not yet calved						
Pinkeye	23.9	(5.7)	29.2	(4.6)	19.1	(3.2)
Respiratory disease	32.5	(6.0)	38.3	(4.9)	24.3	(3.6)
Other	6.7	(2.0)	8.9	(2.5)	5.4	(1.7)

Of operations that used oral or injectable antibiotics to treat specific diseases, the highest percentage cited the local veterinary practitioner as the primary influence when deciding which antibiotics to use.

e. For operations that used oral or injectable antibiotics to treat unweaned calves and replacement heifers weaned but not yet calved, percentage of operations by disease treated and by primary influence on decision about which antibiotics to use

	Percent Operations																	
	Primary Influence																	
	Trade journals		Other producers		Local veterinary practitioner		Consulting or second-opinion veterinarian		Supplier of antibiotics other than veterinarian		Other		No other influence					
Disease	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error				Total
Unweaned calves																		
Pinkeye	0.1	(0.1)	3.1	(1.5)	63.9	(5.1)	3.0	(1.5)	13.2	(4.0)	3.9	(1.7)	12.8	(3.8)				100.0
Respiratory disease	0.1	(0.1)	4.4	(1.4)	66.1	(4.3)	4.5	(2.0)	11.2	(3.0)	2.4	(1.0)	11.3	(3.1)				100.0
Digestive disease	0.1	(0.1)	9.3	(4.9)	65.1	(5.7)	4.7	(1.9)	10.0	(3.2)	2.4	(1.1)	8.4	(3.5)				100.0
Other	0.0	(—)	3.3	(2.9)	56.3	(10.6)	5.6	(5.0)	14.1	(9.2)	1.5	(1.2)	19.2	(7.4)				100.0
Replacement heifers weaned but not yet calved																		
Pinkeye	0.1	(0.1)	4.4	(2.1)	62.2	(5.5)	4.0	(2.2)	12.8	(4.4)	7.6	(3.0)	8.9	(3.2)				100.0
Respiratory disease	1.1	(1.0)	9.0	(4.3)	65.2	(5.3)	4.3	(1.9)	10.8	(3.3)	2.8	(1.2)	6.8	(2.7)				100.0
Other	0.0	(—)	1.0	(0.8)	71.7	(9.6)	0.5	(0.4)	15.2	(9.2)	0.1	(0.1)	11.5	(4.5)				100.0

f. Percentage of operations that treated any cattle or calves in 2007 at least once with oral or injectable antibiotics for any diseases or disorders, by cattle class and by disease treated

Disease	Percent operations	Std. error
Unweaned calves		
Respiratory	22.3	(2.4)
Digestive	19.3	(2.5)
Pinkeye	11.3	(1.9)
Navel	2.6	(0.6)
Other	3.3	(0.9)
Any	40.2	(3.2)
Weaned replacement		
Respiratory	7.7	(1.6)
Digestive	1.1	(0.6)
Pinkeye	3.2	(0.9)
Lameness	1.4	(0.3)
Other	0.3	(0.2)
Any	12.9	(2.0)
Cows		
Respiratory	6.5	(1.5)
Digestive	2.0	(1.0)
Pinkeye	8.3	(1.8)
Reproductive	4.6	(1.2)
Abortion	0.3	(0.1)
Lameness	11.3	(1.8)
Other	2.7	(1.0)
Any	28.3	(2.9)

A higher percentage of younger animals (unweaned calves and replacement heifers) than mature cows were treated at least once with oral or injectable antibiotics.

g. Percentage of cattle or calves treated at least once with oral or injectable antibiotics for any diseases or disorders, by cattle class

Cattle class	Percent treated*	Std. error
Unweaned calves	7.2	(0.7)
Replacement heifers weaned but not yet calved	6.0	(1.3)
Cows	1.9	(0.3)

*Number of treated animals divided by inventory on October 1, 2007, for heifers and cows. For unweaned calves, the number treated was divided by the number of calves weaned or expected to be weaned in 2007.

On operations that used oral or injectable antibiotics in 2007 to treat affected/sick animals for any disease or disorder, 3.8 percent of unweaned calves were affected with respiratory disease, and most of these calves (97.0 percent) were treated with injectable antibiotics. A higher percentage of unweaned calves with respiratory disease and other disease were treated with injectable antibiotics compared to oral antibiotics.

h. For operations that treated any affected/sick cattle or calves in 2007 with oral or injectable antibiotics, percentage of *unweaned calves* on these operations that were affected/sick and percentage of these affected/sick calves treated with oral or injectable antibiotics, by disease treated

			Of the affected/sick calves, percent treated by administration route[2]			
	Percent affected/sick calves[1]		Oral antibiotic		Injectable antibiotic	
Disease	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error
Respiratory	3.8	(0.6)	7.6	(2.3)	97.0	(1.5)
Diarrhea/scours or other digestive	3.5	(0.5)	60.6	(7.0)	57.4	(8.2)
Pinkeye	2.2	(0.5)	20.5	(15.7)	77.5	(15.4)
Navel infection	0.2	(0.1)	36.7	(19.9)	70.2	(21.5)
Other	0.2	(0.1)	19.3	(11.4)	94.0	(4.5)

[1]Affected calves as a percentage of calves weaned or expected to be weaned during 2007.
[2]Treated calves as a percentage of calves affected.

Relatively few operations (less than 10 percent for any disease) used oral antibiotics to treat unweaned calves in 2007. When oral antibiotics were used, the primary antibiotics used were generally split equally between tetracyclines and sulfonamides. The use of oral antibiotics was more common for treating unweaned calves with diarrhea or other digestive problems than for other diseases.

Overall, 20.9 percent of operations used injectable antibiotics to treat some unweaned calves for respiratory disease in 2007. In most cases (8.3 percent of all operations and 39.7 percent of those treating) the primary antibiotic used was tetracycline. Use of injectable antibiotics for treatment of diarrhea or other digestive problems in unweaned calves occurred on 13.4 percent of operations. Most commonly, tetracycline was used to treat these calves (4.7 percent of operations). However, on an estimated 4.0 percent of operations, fluoroquinolones were the primary antibiotic used to treat diarrhea or digestive disease in unweaned calves, which is an illegal use of fluoroquinolones. The Food and Drug Administration has approved the use of fluoroquinolones in cattle for the treatment of respiratory disease but has prohibited its use for other indications. The estimate for use of fluoroquinolones for the treatment of digestive disease in beef calves is based on producer responses to a questionnaire. The actual use of fluoroquinolones for this indication was not validated nor was there an attempt to determine the reasons for this use. Given that only 3.5 percent of unweaned calves experienced clinical diarrhea or other digestive problems and that only about half of these calves were treated with an injectable antibiotic (57.4 percent), the overall number of calves potentially treated with a fluoroquinolone for an illegal indication is very small. Some of these calves may have experienced concurrent respiratory disease which would be a legal indication for fluoroquinolone use. Still, the finding suggests a need to continue to educate beef producers and veterinarians on appropriate and approved uses of antibiotics. Such education has been a component of the Beef Quality Assurance guidelines distributed by the National Cattlemen's Beef Association (see http://www.bqa.org). Since producers cite veterinarians as an important source for information on all uses of antibiotics, including the selection of antibiotics to use in unweaned calves with diarrhea or digestive disease, efforts by veterinary organizations to educate and encourage their members to help producers make appropriate choices of antibiotics will continue to be important.

i. Percentage of operations that used oral or injectable antibiotics to treat *unweaned calves* in 2007, by primary antibiotic used and by disease treated

	Percent Operations									
	Disease									
	Respiratory		Diarrhea/ scours or other digestive		Pinkeye		Navel infection		Other	
Primary antibiotic	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error
Oral										
Sulfonamides	0.7	(0.2)	3.6	(0.7)	0.1	(0.0)	0.2	(0.1)	0.2	(0.1)
Tetracyclines	0.8	(0.5)	2.8	(1.2)	1.0	(0.8)	0.0	(—)	0.0	(0.0)
Aminoglycosides	0.0	(—)	0.5	(0.3)	0.0	(—)	0.0	(—)	0.0	(—)
None	98.5	(0.5)	93.1	(1.4)	98.9	(0.8)	99.8	(0.1)	99.8	(0.1)
Total	100.0		100.0		100.0		100.0		100.0	
Injectable										
Sulfonamides	0.0	(0.0)	0.9	(0.7)	0.0	(—)	0.0	(—)	0.0	(—)
Noncephalosporin beta-lactams	1.5	(0.8)	0.2	(0.1)	1.4	(0.6)	0.9	(0.3)	0.2	(0.1)
Tetracyclines	8.3	(1.7)	4.7	(1.4)	8.8	(1.7)	1.0	(0.4)	2.3	(0.8)
Aminoglycosides	0.2	(0.2)	0.4	(0.4)	0.1	(0.1)	0.1	(—)	0.0	(—)
Macrolides	2.7	(0.6)	0.7	(0.3)	0.1	(0.1)	0.0	(0.0)	0.4	(0.3)
Cephalosporins	1.0	(0.5)	0.6	(0.2)	0.0	(0.0)	0.0	(0.0)	0.1	(0.0)
Florfenicol	4.7	(1.1)	1.9	(0.6)	0.0	(0.0)	0.1	(0.1)	0.2	(0.1)
Fluoroquinolones	2.5	(0.8)	4.0	(1.2)	0.0	(—)	0.1	(0.1)	0.0	(—)
None	79.1	(2.3)	86.6	(2.1)	89.6	(1.8)	97.8	(0.5)	96.8	(0.9)
Total	100.0		100.0		100.0		100.0		100.0	

For operations that used oral or injectable antibiotics in 2007 to treat affected/sick animals for any disease or disorder, 3.2 percent of replacement heifers on these operations were affected with respiratory disease, and the majority of these heifers (84.4 percent) were treated with injectable antibiotics. A higher percentage of replacement heifers with respiratory disease and lameness/footrot were treated with injectable antibiotics than were treated with oral antibiotics.

j. For operations that treated any affected/sick cattle or calves in 2007 with oral or injectable antibiotics, percentage of *replacement heifers* on these operations that were affected/sick and percentage of these affected/sick heifers treated with oral or injectable antibiotics, by disease treated

			Percent treated[2] with…			
	Percent affected/sick heifers[1]		Oral antibiotic		Injectable antibiotic	
Disease	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error
Respiratory	3.2	(0.7)	9.1	(4.3)	84.4	(9.1)
Diarrhea/other digestive	2.5	(1.7)	95.3	(4.1)	44.7	(32.5)
Pinkeye	2.1	(0.8)	46.7	(19.4)	53.3	(19.4)
Lameness/footrot	0.6	(0.1)	28.8	(12.3)	90.5	(5.4)
Other	0.0	(0.0)	5.6	(6.4)	100.0	(—)

[1]Affected heifers as a percentage of beef-cow replacement heifers, weaned or older, on the operations on October 1, 2007.
[2]Treated heifers as a percentage of heifers affected.

Photograph courtesy of Geni Wren "Bovine Veterinarian" magazine.

Very few operations (less than 1 percent) used oral antibiotics to treat any disease condition in replacement heifers in 2007. In addition, less than 8 percent of operations treated any replacement heifers with injectable antibiotics for any individual disease in 2007. The most common use of antibiotics in this age class of animals was for treatment of respiratory disease. When injectable antibiotics were used to treat replacement heifers for respiratory disease, the primary antibiotics were tetracycline and beta-lactams (2.5 and 2.1 percent of operations, respectively).

k. Percentage of operations that used oral or injectable antibiotics to treat *replacement heifers* in 2007, by primary antibiotic used and by disease treated

	Percent Operations									
	Disease									
	Respiratory		Diarrhea or other digestive		Pinkeye		Lameness/ footrot		Other	
Primary antibiotic class	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error
Oral										
Sulfonamides	0.2	(0.1)	0.1	(0.0)	0.0	(0.0)	0.2	(0.1)	0.0	(0.0)
Tetracyclines	0.0	(0.0)	0.0	(0.0)	0.8	(0.7)	0.0	(—)	0.0	(—)
None	99.8	(0.1)	99.9	(0.0)	99.2	(0.7)	99.8	(0.1)	100.0	(0.0)
Total	100.0		100.0		100.0		100.0		100.0	
Injectable										
Sulfonamides	0.0	(0.0)	0.0	(—)	0.0	(—)	0.0	(—)	0.0	(—)
Noncephalosporin beta-lactams	2.1	(1.2)	0.0	(0.0)	0.3	(0.1)	0.3	(0.2)	0.2	(0.1)
Tetracyclines	2.5	(0.8)	0.4	(0.3)	1.9	(0.6)	0.8	(0.2)	0.1	(0.1)
Macrolides	0.7	(0.2)	0.0	(0.0)	0.0	(—)	0.0	(0.0)	0.0	(—)
Cephalosporins	0.5	(0.4)	0.0	(—)	0.1	(0.1)	0.0	(0.0)	0.0	(—)
Florfenicol	1.1	(0.5)	0.1	(0.1)	0.0	(0.0)	0.1	(0.1)	0.0	(—)
Fluoroquinolones	0.7	(0.5)	0.5	(0.4)	0.0	(0.0)	0.0	(—)	0.0	(—)
None	92.4	(1.6)	99.0	(0.6)	97.7	(0.6)	98.8	(0.3)	99.7	(0.2)
Total	100.0		100.0		100.0		100.0		100.0	

On operations that treated any cattle or calves with oral or injectable antibiotics, less than 1 of 100 cows were affected with any specific disease or disorder. For cows affected, a higher percentage received injectable antibiotics than oral antibiotics for all diseases and disorders.

I. For operations that treated any affected/sick cattle or calves in 2007 with oral or injectable antibiotics, percentage of *cows* on these operations that were affected/sick and percentage of these affected/sick cows that were treated with oral or injectable antibiotics, by disease or disorder treated

	Percent affected/sick cows[1]		Percent affected/sick cows treated with[2] . . .			
			Oral antibiotic		Injectable antibiotic	
Disease	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error
Respiratory	0.4	(0.1)	2.4	(1.6)	99.7	(0.2)
Diarrhea or other digestive	0.1	(0.0)	9.5	(5.5)	86.6	(8.1)
Pinkeye	0.9	(0.2)	14.0	(11.9)	81.3	(11.9)
Reproductive (retained placenta/uterine infection)	0.3	(0.1)	5.3	(2.8)	95.6	(3.0)
Abortion	0.0	(0.0)	13.5	(12.9)	73.0	(16.2)
Lameness/footrot	0.8	(0.1)	12.1	(4.4)	95.0	(2.7)
Other	0.1	(0.0)	0.8	(0.7)	79.9	(15.1)

[1]Affected cows as a percentage of total beef cows on the operations on October 1, 2007.
[2]Treated cows as a percentage of cows affected.

Very few operations used oral antibiotics to treat cows for any specific disease condition in 2007. The most common disease condition prompting use of an injectable antibiotic was lameness or footrot in cows, which occurred on 10.1 percent of operations in 2007. The most common primary injectable antibiotic used for treatment of cows with lameness was tetracycline, which was used on 7.8 percent of operations.

m. Percentage of operations by primary antibiotic used to treat *cows* in 2007

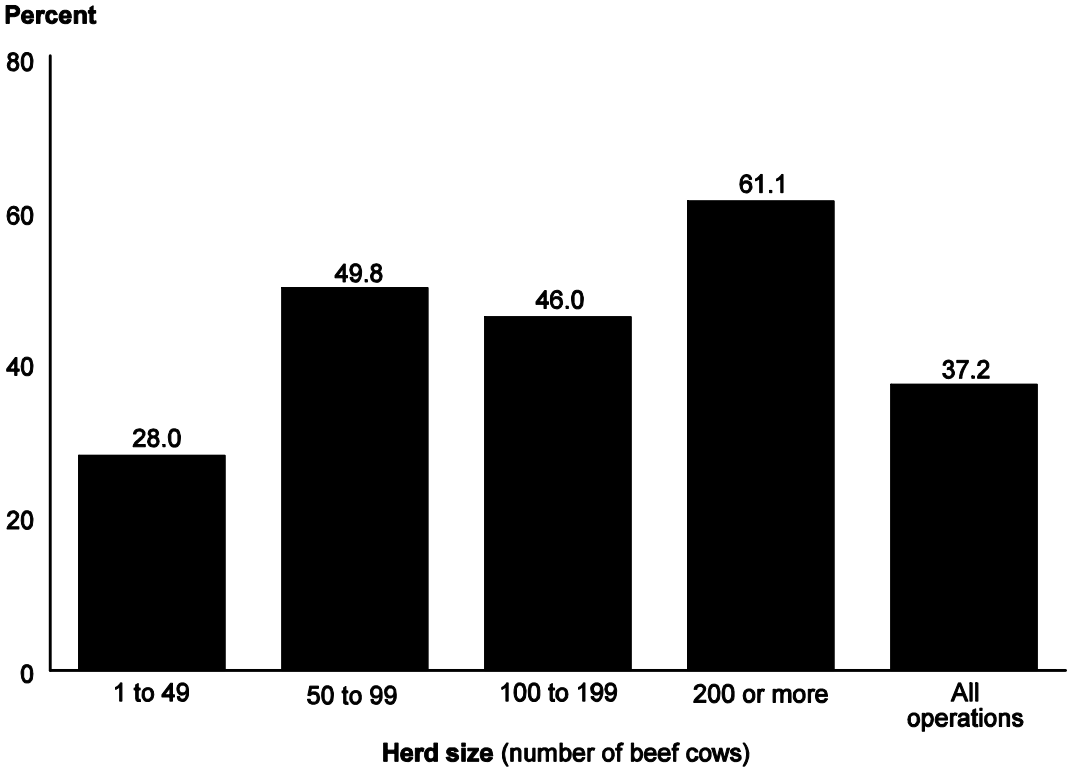
	Percent Operations													
	Disease													
	Respira-tory		Diarrhea/ scours or other digestive		Pinkeye		Reproduc-tive		Abortion		Lameness/ footrot		Other	
Primary antibiotic	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error
Oral														
Sulfona-mides	0.1	(0.1)	0.1	(0.1)	0.0	(—)	0.1	(0.0)	0.0	(—)	0.7	(0.2)	0.0	(0.0)
Tetra-cyclines	0.0	(0.0)	0.0	(0.0)	0.7	(0.7)	0.1	(0.1)	0.0	(0.0)	0.3	(0.3)	0.0	(0.0)
None	99.9	(0.1)	99.9	(0.1)	99.3	(0.7)	99.8	(0.1)	100.0	(0.0)	99.0	(0.3)	100.0	(0.0)
Total	100.0		100.0		100.0		100.0		100.0		100.0		100.0	
Injectable														
Sulfona-mides	0.0	(—)	0.0	(—)	0.0	(—)	0.0	(—)	0.0	(—)	0.1	(0.1)	0.1	(0.1)
Noncephalo-sporin beta-lactams	0.8	(0.5)	0.0	(0.0)	0.8	(0.4)	1.1	(0.4)	0.1	(0.1)	0.3	(0.2)	1.0	(0.7)
Tetra-cyclines	4.1	(1.4)	0.3	(0.2)	6.2	(1.5)	2.2	(0.9)	0.1	(0.1)	7.8	(1.6)	1.4	(0.7)
Amino-glycosides	0.0	(—)	0.0	(—)	0.1	(0.1)	0.6	(0.6)	0.0	(—)	0.0	(--)	0.0	(--)
Macrolides	0.2	(0.1)	0.2	(0.2)	0.0	(0.0)	0.0	(0.0)	0.0	(—)	0.9	(0.4)	0.2	(0.2)
Cephalo-sporins	0.6	(0.4)	0.0	(—)	0.0	(0.0)	0.0	(—)	0.0	(—)	0.1	(0.0)	0.0	(—)
Florfenicol	0.5	(0.2)	0.6	(0.6)	0.4	(0.4)	0.0	(—)	0.1	(0.1)	0.9	(0.4)	0.0	(—)
Fluoro-quinolones	0.2	(0.1)	0.7	(0.7)	0.0	(—)	0.0	(—)	0.0	(—)	0.0	(—)	0.0	(—)
None	93.6	(1.5)	98.2	(1.0)	92.5	(1.6)	96.1	(1.1)	99.7	(0.1)	89.9	(1.7)	97.3	(1.0)
Total	100.0		100.0		100.0		100.0		100.0		100.0		100.0	

About 4 of 10 operations (37.2 percent) generally treated calves 7 days and older with antibiotics for diarrhea (scours). The percentage of operations that gave antibiotics to calves 7 days or older for diarrhea ranged from 28.0 percent of operations with 1 to 49 beef cows to 61.1 percent of operations with 200 or more beef cows.

n. Percentage of operations that generally treated calves 7 days and older with antibiotics for diarrhea (scours), by herd size

Percent Operations									
Herd Size (number of beef cows)									
1–49		50–99		100–199		200 or more		All operations	
Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error	Pct.	Std. error
28.0	(5.2)	49.8	(6.8)	46.0	(6.1)	61.1	(4.7)	37.2	(3.5)

Percentage of operations that generally treated calves 7 days and older with antibiotics for diarrhea (scours), and by herd size



The percentage of operations that generally treated calves 7 days and older with antibiotics for diarrhea did not differ substantially across regions.

o. Percentage of operations that generally treated calves 7 days and older with antibiotics for diarrhea (scours), by region

Percent Operations					
Region					
West		Central		Southeast	
Percent	Std. error	Percent	Std. error	Percent	Std. error
48.5	(6.2)	47.3	(5.5)	29.9	(5.0)

Section III: Fecal Sample Evaluations

A. Study Methods for Biological Sampling and Testing for Enteric Bacteria

1. Sample collection

Based on laboratory capacity, a total sample size of 175 operations was set. One-hundred operations were designated for collections, which took place from January 14 to April 15, 2008. Another 75 operations were designated for collection, which took place from July 7 to August 31, 2008. In both sampling periods the total number of herds was allocated to the 24 States, roughly in proportion to the number of beef cows in those States. State coordinators selected a convenience sample of the operations for fecal sampling from operations participating in the NAHMS Beef 2007–08 study that had agreed to sample collection.

On each operation, 30 to 40 fecal samples from adult beef cows were collected. The number of samples collected depended on the number of cows in the herd. For herds with 1 to 30 cows, the number of samples collected was equal to the number of cows in the herd. For herds with 41 to 100 cows, 35 samples were collected. For herds with 101 or more cows, 40 samples were collected. Collectors were instructed to collect only fresh fecal samples off the ground across a distributed area. Each 10-gram fecal sample was placed into Whirl-Pak® bags using a clean tongue depressor. This was done to ensure that collected samples represented different animals. Fecal samples were immediately chilled on ice packs and shipped for overnight delivery to the laboratory.

2. Culture methods

All samples were cultured for *Salmonella*. A subset of the samples was cultured for *Campylobacter*, *Enterococcus*, *Escherichia coli,* and *Clostridium difficile*. When the samples were processed for *Salmonella*, every other sample was cultured for *Campylobacter* and *C. difficile* and every fourth sample was cultured for *E. coli* and *Enterococcus*.

Salmonella: Feces (1 g) were incubated in 10 mL of GN Hajna (Difco Laboratories, Detroit, MI) for 18–24 h at 37°C, and tetrathionate broth (Difco) for 40–48 h at 37°C. After initial enrichments, aliquots (100 µL) were transferred to 10 mL of Rappaport-Vassiliadis R10 broth (Difco) which were incubated for 18–24 h at 37°C. Ten-µL aliquots of Rappaport-Vassiliadis R10 broth were then streaked onto Xylose-Lysine-Tergitol-4 (Difco) and BG Sulfa (Difco) agar. Plates were incubated for 18–24 h at 37°C. Isolated colonies characteristic of *Salmonella* were inoculated into triple sugar iron and lysine iron agar slants for biochemical confirmation. Presumptive positive isolates were serogrouped using serogroup specific antisera (Difco) and sent to the National Veterinary Services Laboratories (Ames, IA) for serotyping.

Campylobacter: Fecal samples were diluted 1:9 (wt/vol) in sterile phosphate-buffered saline (PBS, 0.1 M, pH 7.2) and 100-µL aliquots were inoculated onto Campy-Cefex agar plates (Stern et al., 1992) and into Bolton Broth enrichment media (1-mL broth enrichments in Falcon 353047 tissue culture plates, 24 wells/ Becton

Dickinson Labware, Franklin Lakes, NJ 07417). Agar plates and enrichment broth were incubated for 36–48 h at 42°C under microaerobic conditions (5% O2, 10% CO_2 and 85% N_2). Presumptive *Campylobacter* colonies were selected by observation of cellular morphology and motility using a wet mount under phase-contrast microscopy. Isolates were identified by species using a commercial multiplex PCR (BAX® PCR, DuPont Qualicon, Wilmington, DE).

Enterococcus spp.: 100-µL aliquots of fecal dilutions (1:9 wt/vol, in PBS) were inoculated into 24 well tissue culture plates (Becton Dickinson Labware, Franklin Lakes, NJ 07417) containing 1 mL of Enterococcosel broth (Becton Dickinson, Sparks MD 21152) per well. The plates were incubated for 18–24 h at 37°C, followed by streaking for isolation onto Enterococcosel agar (Becton Dickinson). Isolates were identified by species using a multiplex PCR [27].

Non-type specific *E. coli*: 100-µL aliquots of fecal dilutions (1:9 wt/vol, in PBS) were streaked for isolation onto CHROMagar EEC™ (Hardy Diagnostics, Santa Maria, CA) plates. The plates were incubated for 18–24 h at 42°C, after which colonies indicative of *E. coli* were selected.

C. difficile: Two isolation methods single shock (SS) and double shock (DS) and two plating methods (BA and CCFA; Remel, Lenexa, KS) were employed for the isolation of *C. difficile*. All plating media and broth were prereduced in an anaerobic chamber (5% hydrogen, 5% CO_2, balanced nitrogen; Bactron Anaerobic, model BacII, Sheldon Manufacturing, Cornelius, OR) 24 h prior to use. The SS method was performed as described by Arroyo et al. (2005). The DS method was performed as follows. In brief, 2 g of fecal sample was mixed with 6 mL of absolute ethanol in a 15-mL conical tube and left at room temperature for 60 min. The sample was then centrifuged at 3,800 | g for 10 min at 4°C. The resulting pellet was disrupted with a swab, which was then used to inoculate 9.0 mL of prereduced TCCFB in screw-capped tubes and incubated aerobically at 37°C for 7 d. After incubation, 3.0 mL was transferred into a 15-mL conical tube, mixed with an equal amount of absolute ethanol, and left at room temperature for 60 min, at which time the sample was centrifuged at 4,600 | g for 30 min at 4°C. The supernatant fluid was discarded; the pellet was mixed with a sterile swab, which was subsequently used to streak prereduced BA and CCFA plates and incubated anaerobically in the aforementioned chamber at 37°C for 72 h (5% hydrogen, 5% CO_2, balanced nitrogen).

Confirmation of *C. difficile*—Plates were examined for typical *C. difficile* colonies by using the following criteria: observation of yellow-green fluorescence UV light (350 nm) and production of a horse-manure like odor. Suspect colonies were subcultured to CCFA and incubated anaerobically at 37°C for 72 h for purity prior to further testing. After incubation, the colonies were observed for a flat, ground-glasslike surface with irregular edge morphology, as well as the fluorescence and odor as described above. Additionally, a Gram stain was done to confirm that they were gram-positive and posed long, thin, straight rods under a |1,000 light microscope. Biochemical

confirmation included testing for the production of L-proline aminopeptidase (Pro-Disc, Remel, Carr-Scarborough Microbiologicals, Inc., Decatur, GA). Definitive confirmation was made with 16S rDNA PCR, as described by Kikuchi et al. (2002). All positive isolates were stored in 10 mL of cooked meat medium in parafilmed screw-capped tubes at room temperature after 48 h of anaerobic growth initiation at 37°C.

3. Antimicrobial resistance evaluation

The resistance profile for isolates was evaluated using methods consistent with the National Antimicrobial Resistance Monitoring System (NARMS). Details of the NARMS antimicrobial resistance testing methods can be found at: http://www.fda.gov/AnimalVeterinary/SafetyHealth/AntimicrobialResistance/NationalAntimicrobialResistanceMonitoringSystem/default.htm. These methods apply to the *Salmonella, Campylobacter, Enterococcus,* and *E. coli* isolates.

Salmonella, E. coli, Campylobacter, and *Enterococcus* isolates were tested for susceptibility to a panel of antimicrobials using a broth microdilution system. The *Salmonella* and *E. coli* panel consisted of 15 antimicrobial drugs[1], the *Campylobacter* panel 9[2], and *Enterococcus* panel 17[3]. Minimum inhibitory concentration (MIC) values were used to categorize the isolates as susceptible, intermediate, or resistant to the antimicrobial tested based on breakpoint values used in the NARMS.

[1] Amikacin, amoxicillin-clavulanic acid, ampicillin, cefoxitin, ceftiofur, ceftriaxone, chloramphenicol, ciprofloxacin, gentamicin, kanamycin, nalidixic acid, streptomycin, sulfamethoxazole, tetracycline, trimethoprim-sulfamethoxazole.
[2] Azithromycin, ciprofloxacin, clindamycin, erythromycin, florfenicol, gentamicin, nalidixic acid, telithromycin, tetracycline.
[3] Chloramphenicol, ciprofloxacin, daptomycin, erythromycin, flavomycin, gentamicin, kanamycin, lincomycin, linezolid, nitrofurantoin, penicillin, streptomycin, synercid, tetracycline, tigecycline, tylosin, vancomycin.

a. Breakpoints used for susceptibility testing of *Salmonella* and *E. coli*[1,2]

Antimicrobial class	Antimicrobial agent	Breakpoints (µg/mL) Susceptible (less than or equal)	Intermediate	Resistant (greater than or equal)
Aminoglycosides	Amikacin	16	32	64
	Gentamicin	4	8	16
	Kanamycin	16	32	64
	Streptomycin	32	NA	64
β-lactam/β-lactamase inhibitor combinations	Amoxicillin-clavulanic acid	8/4	16/8	32/16
Cephems	Cefoxitin	8	16	32
	Ceftiofur	2	4	8
	Ceftriaxone[2]	8	16–32	64
Folate pathway inhibitors	Sulfamethoxazole/ sulfisoxazole[3]	256	NA	512
	Trimethoprin-sulfamethoxazole	2/38	NA	4/76
Penicillin	Ampicillin	8	16	32
Phenicol	Chloramphenicol	8	16	32
Quinolones	Ciprofloxacin	1	2	4
	Nalidixic acid	16	NA	32
Tetracyclines	Tetracycline	4	8	16

[1]Breakpoints were adopted from CLSI (Clinical and Laboratory Standards Institute), except for streptomycin, which has no CLSI breakpoints.
[2]CLSI revised the breakpoints for ceftriaxone in its M100-S20 document published in January 2010. The new resistant breakpoint is ≥4 µg/mL. The old breakpoints were used in this NAHMS report.
[3]Sulfamethoxazole was tested from 1996 through 2003 and was replaced by sulfisoxazole in 2004.
Source: USDA. National Antimicrobial Resistance Monitoring System. 2007 Executive Report.

b. Breakpoints used for susceptibility testing of *Campylobacter*[1]

Antimicrobial class	Antimicrobial agent	Breakpoints (µg/mL) Susceptible (less than or equal)	Intermediate	Resistant (greater than or equal)
Aminoglycosides	Gentamicin	2	4	8
Ketolides	Telithromycin	4	8	16
Lincosamides	Clindamycin	2	4	8
Macrolides	Azithromycin	2	4	8
	Erythromycin	8	16	32
Phenicol	Florfenicol[2]	4	NA	NA
Quinolones	Ciprofloxacin	1	2	4
	Nalidixic acid	16	32	64
Tetracyclines	Tetracycline	4	8	16

[1]Breakpoints were adopted from CLSI (Clinical and Laboratory Standards Institute) when available.
[2]For florfenicol, only a susceptible breakpoint (≤4 µg/mL) has been established. In this report, isolates with an MIC ≥8 µg/mL are categorized as resistant.
Source: USDA. National Antimicrobial Resistance Monitoring System. 2007 Executive Report.

c. Breakpoints used for susceptibility testing of *Enterococcus*[1]

Antimicrobial class	Antimicrobial agent	Breakpoints (µg/mL) Susceptible (less than or equal)	Intermediate	Resistant (greater than or equal)
Aminoglycosides	Gentamicin	4	8	16
	Kanamycin[2]	512	NA	1,024
	Streptomycin	512	NA	1,024
Glycopeptides	Vancomycin	4	8, 16	32
Glycylcycline	Tigecycline[2 3]	0.25	NA	NA
Lincosamides	Lincomycin[2]	2	4	8
Lipopeptides	Daptomycin[2 4]	4	NA	NA
Macrolides	Erythromycin	0.5	1, 2, 4	8
	Tylosin[2]	8	16	32
Nitrofurans	Nitrofurantoin	32	64	128
Oxazolidinones	Linezolid	2	4	8
Penicillins	Penicillin	8	NA	16
Phenicol	Chloramphenicol	8	16	32
Phosphoglycolipids	Flavomycin[2]	8	16	32
Fluoroquinolone	Ciprofloxacin	1	2	4
Streptogramins	Quinupristin/ Dalfopristin	1	2	4
Tetracyclines	Tetracycline	4	8	16

[1] Breakpoints were adopted from CLSI (Clinical and Laboratory Standards Institute). In 2008, *Enterococcus* plate CMV3AGPF replaced CMV2AGPF midyear. MIC ranges for *Enterococcus* reflect the smaller range.

[2] No CLSI interpretive criteria for this bacterium/antimicrobial currently available.

[3] Only a susceptible breakpoint (≤0.25 µg/mL) has been established. Isolates with an MIC ≥0.5 µg/mL are reported as nonsusceptible.

[4] Only a susceptible breakpoint (≤ µg/mL) has been established. Isolates with an MIC ≥0.8 µg/mL are reported as nonsusceptible.

For the *C. difficile* isolates, antimicrobial resistance was determined using the E-test with nine antimicrobial drugs.[1] Again, the isolates were categorized as susceptible, intermediate, or resistant to the antimicrobial tested based on breakpoint values shown below.

d. Antimicrobials used in susceptibility testing of *Clostridium difficile*

Antimicrobial	Class	Category	Reason to test	Range tested (µg/mL)	Resistance breakpoint (greater than or equal) [µg/mL]	References
Linezolid	Oxazolidinone	Both	Risk factor for CDAD*	0.016-256	4	Zheng et al., 2007
Amoxicillin-clavulanic acid	β-lactam	Bactericidal	Risk factor for CDAD	0.016-256	16	CLSI, 2007
Ampicillin	Penicillin	Bactericidal	Risk factor for CDAD	0.016-256	2	CLSI, 2007
Clindamycin	Lincosamide	Bacteriostatic	Risk factor for CDAD	0.016-256	8	CLSI, 2007
Erythromycin	Macrolide	Bacteriostatic	Risk factor for CDAD	0.016-256	256	Drudy et al., 2007
Metronidazole	Imidazole	Bactericidal	Treatment for CDAD	0.016-256	32	CLSI, 2007
Levoflaxacin	Fluoro-quinolone	Bactericidal	Risk factor for CDAD	0.002-32	8	Martin et al., 2008
Rifampicin	Rifamycin	Bactericidal	Treatment for CDAD	0.002-32	32	O'Conner et al., 2008
Vancomycin	Glycopeptide	Bactericical	Treatment for CDAD	0.016-256	32	Indra et al., 2008

*CDAD = *Clostridium difficile* associated disease.

[1] Linezolid, amoxicillin-clavulanic acid, ampicillin, clindamycin, erythromycin, levofloxacin, metronidazole, rifampicin, and vancomycin.

4. Comparison of operations by whether samples were submitted

There were no differences in the number of producers who did or did not submit fecal samples based on herd size (p=0.77) or region (p=0.25). A chi-square test using SAS Proc Freq was used to test for an association between sample submission and herd size (region).

a. Number of operations that submitted samples, by size of operation

	Number of Operations **Herd Size** (number of beef cows)				
Samples submitted	**1–49**	**50–99**	**100–199**	**200 or more**	**Total**
Yes	49	26	42	56	173
No	114	70	83	127	394

b. Number of operations that submitted samples, by region

	Number of Operations **Region**		
Samples submitted	**West**	**Central**	**Southeast**
Yes	39	54	80
No	99	142	153

B. Sample Testing Results

Overall, fecal samples were collected and tested on 173 operations. In the first collection (January–April, 2008), 3,266 samples were collected on 97 operations. In the second collection (July–August, 2008) 2,527 samples were collected on 76 operations.

1. *Salmonella*

Operation level prevalence—Among the 173 operations sampled, *Salmonella* was cultured from 1 or more samples on 16 operations (9.2 percent). There was no apparent relationship between *Salmonella* culture status and operation size (P=0.39) or region (P=0.46). There was a difference (P=0.009) in the proportion of operations with positive samples based on timing of the sampling, with 12 of the 16 positive operations (75.0 percent) being collected in period 2 (July 7–August 31).

a. Number and percentage of operations positive for *Salmonella*, by size of operation*

	Number of Operations Herd Size (number of beef cows)				
	1–49	50–99	100–199	200 or more	Total
Number tested	49	26	42	56	173
Number positive	2	2	6	6	16
Percent positive	4.1	7.7	14.3	10.7	9.2

*P value difference by herd size = 0.39.

b. Number and percentage of operations positive for *Salmonella*, by region*

	Region			
	West	Central	Southeast	Total
Number tested	39	54	80	173
Number positive	5	3	8	16
Percent positive	12.8	5.6	10.0	9.2

*P value difference by region = 0.46.

None of the antibiotic-use practices on the operations was associated with the ability to recover *Salmonella* on the operation.

c. Association between antibiotic-use practices and presence of *Salmonella* on the operations

Response	Herds positive	Herds negative	P-value
Antibiotic use in feed			
Any cattle or calves[1]			
Yes	3	55	0.19
No	13	102	
Antibiotic use—oral or injection			
Any cattle or calves[1]			
Yes	14	137	1.00
No	2	20	
Unweaned calves[2]			
Yes	9	99	0.59
No	7	58	
Replacement heifers[2]			
Yes	6	53	0.76
No	10	104	
Cows[2]			
Yes	8	76	0.90
No	8	81	

[1]Operation policy to use oral or injectable antibiotics to treat any animals
[2]Treatment of one or more animals of the specified class with either oral or injectable antibiotics in 2007.

Sample level prevalence—Of the 5,793 samples cultured for *Salmonella*, 31 (0.5 percent) were positive. The number of positive samples per operation ranged from one to eight. There was no apparent relationship between the percentage of samples positive for *Salmonella* and operation size (P=0.61), region (P=0.19), or sampling period (P=0.77). Fourteen of the 31 positive samples (45.1 percent) were collected from July 7–August 31. Among the 31 positive samples, 34 *Salmonella* isolates were evaluated further by serotyping and antibiotic resistance testing.

Isolate characteristics—Two cow-calf operations tested positive for four different *Salmonella* serotypes, and two different serotypes were present on three operations. On all other positive operations, only a single serotype was identified. *S.* Montevideo was the most common serotype (17.6 percent of isolates).

d. Number and percentage of *Salmonella* isolates, and number and percentage of positive operations, by serotype

	Isolates[1] (n=34)		**Operations** (n=16)	
Serotype	**Number**	**Pct.**	**Number**	**Pct.**
Braenderup	2	5.9	2	12.5
Meleagridis	2	5.9	1	6.3
Montevideo	6	17.6	2	12.5
Newport	2	5.9	2	12.5
I 3, 10:-:1,w	2	5.9	1	6.3
I 6,7:k:-	3	8.8	1	6.3
All others[2]	17	50.0	13	81.3
Total	34	100.0	NA	NA

[1]More than one isolate was cultured from two samples.
[2]Three untypable isolates are included here, as well as serotypes with one isolate each (Anatum, Javiana, Lawndale, Mbandaka, Oukam, Rubislaw, Saugas, and seven unnamed serotypes).

Comparison to previous studies—Sample collection methods for the Beef 2007–08 study were similar to those used during the Beef '97 study. The percentage of operations with positive samples and the percentage of samples positive for *Salmonella* were similar between the two studies.

e. Number and percentage of operations, and number and percentage of cows sampled, positive for *Salmonella*

	Operations with at least one positive cow		Positive sampled cows	
Study	**Number**	**Pct.**	**Number**	**Pct.**
Beef '97	21/187	11.2	70/5,049	1.4
Beef 2007–08	16/173	9.2	31/5,793	0.5

All 34 isolates from the Beef 2007–08 study were susceptible to all of the antimicrobial drugs on the panel tested.

f. Percentage of resistant *Salmonella* isolates, by antimicrobial[1]

	Percent Isolates	
Antimicrobial	**Beef '97** (n=78)	**Beef 2007–08** (n=34)
Amikacin	0.0	0.0
Amoxicillin-clavulanic acid	0.0	0.0
Ampicillin	1.3	0.0
Apramycin	0.0	NA
Cefoxitin	NA	0.0
Ceftiofur	0.0	0.0
Ceftriaxone	0.0	0.0
Cephalothin	0.0	NA
Chloramphenicol	0.0	0.0
Ciprofloxacin	0.0	0.0
Gentamicin	2.6	0.0
Kanamycin	0.0	0.0
Nalidixic acid	0.0	0.0
Streptomycin	11.5	0.0
Sulfamethoxazole[2]	11.5	0.0
Tetracycline	2.6	0.0
Ticarcillin	1.3	NA
Trimethoprim-sulfamethoxazole	0.0	0.0
Resistant to two or more antimicrobials	11.5	0.0
Susceptible to all antimicrobials tested[2]	87.2	100.0

[1]Intermediate isolates were classified as susceptible.
[2]Sulfisoxazole replaced sulfamethoxazole in 2007–08.
NA=antimicrobial not included for this study.

Summary—Only about 10 percent of beef cow-calf operations tested *Salmonella* positive in the Beef '97 and Beef 2007–08 studies. Overall, antibiotic-use practices were not associated with the ability to recover *Salmonella* on the operation. Approximately 1 percent of samples were positive for *Salmonella* in Beef '97 and Beef 2007–08. These results suggest that *Salmonella* is not very common on U.S. beef cow-calf operations. It is possible that repeated sampling of these same operations over time could identify more positive operations. Herd size and region of the United States were not associated with the presence of *Salmonella* on operations from the Beef 2007–08 study. Antimicrobial resistance was not observed in any of the *Salmonella* isolates from the Beef 2007–08 study, and very little resistance was seen in isolates from the Beef '97 study. These results suggest that antimicrobial-resistant *Salmonella* are uncommon in U.S. beef cow-calf operations.

2. *Campylobacter*

Operation level prevalence—Campylobacter was identified in one or more samples from beef cows on 77 of 173 of operations (44.5 percent). There was a difference in the proportion of operations with positive *Campylobacter* samples by herd size (P<0.0001) and by region (P=0.008). There was no difference in the proportion of positive operations by sampling period (P=0.24). For the January 14–April 15 sampling period, 47 of 97 of operations (48.5 percent) had one or more positive samples; for the July 7–August 31 sampling period, 30 of 76 of operations (39.5 percent) had one or more positive samples.

a. Number of operations that tested samples for *Campylobacter,* and number and percentage of operations with at least one sample positive for *Campylobacter*, by size of operation

	Percent Operations **Herd Size** (number of beef cows)				
	1–49	**50–99**	**100–199**	**200 or more**	**Total**
Number tested	49	26	42	56	173
Number positive	8	10	23	36	77
Percent positive	16.3	38.5	54.8	64.3	44.5

b. Number of operations that tested samples for *Campylobacter,* and number and percentage of operations with at least one sample positive for *Campylobacter*, by region

	Percent Operations Region			
	West	**Central**	**Southeast**	**Total**
Number tested	39	54	80	173
Number positive	19	32	26	77
Percent positive	48.7	59.3	32.5	44.5

None of the overall measures of antibiotic-use practices on the operations was associated with recovery of *Campylobacter* from fecal samples.

c. Association between antibiotic-use practices and presence of *Campylobacter* on the operations

Response	Herds positive	Herds negative	P-value
Antibiotic use in feed			
Any cattle or calves[1]			
Yes	25	33	0.79
No	52	63	
Antibiotic use—oral or injection			
Any cattle or calves[1]			
Yes	69	82	0.41
No	8	14	
Unweaned calves[2]			
Yes	53	55	0.12
No	24	41	
Replacement heifers[2]			
Yes	29	30	0.38
No	48	66	
Cows[2]			
Yes	43	41	0.09
No	34	55	

[1]Operation policy to use oral or injectable antibiotics to treat any animals.
[2]Treatment of one or more animals of the specified class with either oral or injectable antibiotics in 2007.

Sample level prevalence—Overall, 259 of 2,917 samples (8.8 percent) were culture positive for *Campylobacter*. The prevalence of positive samples was different by herd size (P=0.0002) and by region (P=0.024), with prevalence increasing as herd size increased. Statistical analysis using SAS Proc Genmod accounted for clustering of samples within farms. The proportion of positive samples did not vary by collection period (P=0.097). A total of 10.6 percent of samples collected January 14–April 15 were positive compared with 6.6 percent of samples collected July 7–August 3.

d. Number of cows tested for *Campylobacter,* and number and percentage of cows positive for *Campylobacter*, by size of operation

	Herd Size (number of beef cows)				
	1–49	**50–99**	**100–199**	**200 or more**	**Total**
Number tested	560	456	793	1,108	2,917
Number positive	13	25	84	137	259
Percent positive	2.3	5.5	10.6	12.4	8.8

e. Number of cows tested for *Campylobacter,* and number and percentage of cows positive for *Campylobacter*, by region

	Region			
	West	**Central**	**Southeast**	**Total**
Number tested	651	989	1,277	2,917
Number positive	92	95	72	259
Percent positive	14.1	9.6	5.6	8.9

Isolate characteristics—C. jejuni was recovered from 244 samples on 75 operations, and *C. coli* was recovered from 10 samples on 5 operations. *Campylobacter* of an unknown type was recovered from five samples collected from four operations. Seven operations had more than one species of *Campylobacter* isolated (counting "not typed" as a species).

Antimicrobial resistance—Over half of the *C. jejuni* isolates (56.2 percent) were susceptible to all nine antimicrobials tested. Of the antimicrobials in the following table, ciprofloxacin and erythromycin are especially important because they are often used to treat humans infected with *Campylobacter*. Less than 7 percent of *C. jejuni* isolates were resistant to ciprofloxacin, and less than 1 percent were resistant to erythromycin. The highest percentage of isolates (38.9 percent) were resistant to tetracycline. Of the 10 *C. coli* isolates tested for antimicrobial susceptibility, 6 were resistant to tetracycline, 2 were resistant to ciprofloxacin, and 2 were resistant to nalidixic acid.

f. Percentage of resistant *C. jejuni* isolates, by antimicrobial*

Antimicrobial	**Percent** (n=244)
Azithromycin	0.4
Ciprofloxacin	6.6
Clindamycin	0.8
Erythromycin	0.4
Florfenicol	0.0
Gentamicin	0.0
Nalidixic acid	6.1
Telithromycin	0.0
Tetracycline	38.9
Resistant to two or more antimicrobials	8.2
Susceptible to all nine antimicrobials	56.2

*Intermediate isolates were classified as susceptible.

Summary—Campylobacter was found on less than half of the beef cow-calf operations tested and in less than 10 percent of the collected samples. Antibiotic-use practices were not associated with the ability to recover *Campylobacter* on operations. About 95 percent of the *Campylobacter* isolates were *C. jejuni*. *Campylobacter* was less likely to be isolated from smaller herds and herds in the Southeast region. Relatively few *Campylobacter* isolates were resistant to antimicrobials, and over half of the *C. jejuni* isolates were susceptible to all of the antimicrobials against which they were tested. The highest percentage of resistance was observed for tetracycline. Few isolates were resistant to ciprofloxacin or erythromycin. Resistance to two or more antimicrobials occurred in less than 9 percent of isolates.

3. *Enterococcus*

Operation level prevalence—As expected, nearly all operations (98.3 percent) had at least one sample positive for *Enterococcus*. As such, there were no differences by herd size (P=0.40) or region (P=0.22). Nor were there differences by sampling period (P=0.58). Furthermore, antibiotic-use practices on the operations were not associated with recovery of *Enterococcus* on the operations.

a. Association between antibiotic-use practices and presence of *Enterococcus*

Response	Herds positive	Herds negative	P-value
Antibiotic use in feed			
Any cattle or calves[1]			
Yes	58	0	0.55
No	112	3	
Antibiotic use—oral or injection			
Any cattle or calves[1]			
Yes	148	3	1.00
No	22	0	
Unweaned calves[2]			
Yes	106	2	1.00
No	64	1	
Replacement heifers[2]			
Yes	58	1	1.00
No	112	2	
Cows[2]			
Yes	84	0	0.25
No	86	3	

[1]Operation policy to use oral or injectable antibiotics to treat any animals.
[2]Treatment of one or more animals of the specified class with either oral or injectable antibiotics in 2007.

Sample level prevalence—A total of 1,182 of 1,479 samples (79.9 percent) were culture positive for *Enterococcus*. Again, there were no differences by herd size (P=0.88) or by sampling period (P=0.61). There were differences in the proportion of samples positive by region (P=0.006).

b. Number of cows tested for *Enterococcus*, and number and percentage of cows positive for *Enterococcus*, by region

	Region			
	West	Central	Southeast	Total
Number tested	328	498	653	1,479
Number positive	216	426	540	1,182
Percent positive	65.9	85.5	82.7	79.9

Isolate characteristics—E. faecalis and/or *E. faecium* were found on 43.9 percent of operations. Of the 1,182 positive samples, 11.5 percent and 3.2 percent were *E. faecium* and *E.* faecalis, respectively. The highest percentage of isolates (39.0 percent) were identified as *E.casseliflavus*. Of the operations on which enterococci were found, 83.5 percent had at least one *E. casseliflavus* isolate and 73.5 percent had at least one *E. hirae* isolate. *E. faecium* and *E. faecalis* were found on 38.8 percent and 14.1 percent of positive operations, respectively.

c. Number and percentage of isolates, and number and percentage of positive operations, by *Enterococcus* species

	Isolates* (n=1,182)		**Operations** (n=170)	
Species	**Number**	**Percent**	**Number**	**Percent**
E. casseliflavus	461	39.0	142	83.5
E. hirae	303	25.6	125	73.5
E. mundtii	169	14.3	73	42.9
E. faecium	136	11.5	66	38.8
Not typed	57	4.8	43	25.3
E. faecalis	38	3.2	24	14.1
E. gallinarum	9	0.8	6	3.5
E. durans	6	0.5	5	2.9
E. avium	3	0.3	3	1.8
Total	1,182	100.0	NA	NA

*The number of isolates equals the number of positive samples since only one *Enterococcus* species was identified in each sample.

Antimicrobial resistance—Of the 1,180 isolates tested for antimicrobial susceptibility, 11 (0.9 percent) were susceptible to all 17 antimicrobials. Two isolates were not viable at the time of testing. All of the *E. faecalis* and *E. faecium* isolates were resistant to at least one antimicrobial. Vancomycin resistance is of particular interest since it is used to treat humans with enterococcal infections (McGowan et al., 2006). One *E. casseliflavus* isolate was resistant to vancomycin, but this was determined to be an intrinsic resistance (naturally occurring trait) rather than an acquired resistance. None of the *E. faecalis* or *E. faecium* isolates was resistant to vancomycin. Resistance to quinupristin/dalfopristin (Synercid®) is important because this antimicrobial is used to treat vancomycin-resistant *E. faecium* infections (McGowan et al., 2006). Only 0.7 percent of *E. faecium* and 0.9 percent of other enterococci were resistant to Synercid. Over 90 percent of *E. faecium* and other enterococci were resistant to flavomycin, while none of the *E. faecalis* isolates were resistant to flavomycin. Overall, 100.0, 54.1, and 90.7 percent of the *E. faecalis*, *E. faecium*, and other enterococci, respectively, were resistant to lincomycin.

d. Percentage of resistant *Enterococcus* isolates, by species and by antimicrobial[1]

	Percent Isolates		
Antimicrobial	***E. faecalis*** (n=38)	***E. faecium*** (n=135)	**Other Enterococci** (n=1,007)
Chloramphenicol	0.0	0.7	0.0
Ciprofloxacin	0.0	45.9	4.1
Daptomycin[2]	0.0	0.0	5.3
Erythromycin	0.0	0.7	0.8
Flavomycin	0.0	92.6	90.3
Gentamicin	0.0	0.0	0.0
Kanamycin	0.0	1.5	0.0
Lincomycin	100.0	54.1	90.7
Linezolid	0.0	0.0	0.0
Nitrofurantoin	0.0	3.0	0.1
Penicillin	2.6	0.7	0.4
Streptomycin	0.0	0.0	0.0
Synercid	NA[3]	0.7	0.9
Tetracycline	2.6	12.6	18.2
Tigecycline[2]	0.0	0.0	0.0
Tylosin	0.0	0.0	1.1
Vancomycin	0.0	0.0	0.1[4]

[1]Intermediate isolates were classified as susceptible.
[2]The Clinical and Laboratory Standards Institute has no approved standards for daptomycin and tigecycline susceptibility testing.
[3]*E. faecalis* exhibits an intrinsic resistance to Synercid.
[4]One *E. casseliflavus* isolate was intrinsically resistant to vancomycin.

Summary—Enterococcus was found on 98.3 percent of the beef cow-calf operations tested and in 79.9 percent of the samples collected. There was no association between recovery of *Enterococcus* and antibiotic-use practices. The high prevalence of enterococci was expected, since this organism is a normal inhabitant of the gastrointestinal tract of animals and humans. *E. faecalis* or *E. faecium*, the organisms responsible for most of the human illness caused by enterococci, were found on less than half of operations (43.9 percent). *E. casseliflavus* was the most common species identified. Synercid and vancomycin are two of the more important antimicrobials used in treating human enterococcal infections. There was very little resistance to Synercid and no notable resistance to vancomycin. Resistance to lincomycin and flavomycin was most commonly observed in the isolates from this study.

4. *Escherichia coli*

Operation level prevalence—172 of 173 operations had at least one sample positive for *E. coli*.

Sample level prevalence—Overall 1,147 of 1,479 samples (77.6 percent) were positive for *E. coli*. The proportion of samples positive for *E. coli* was not different by herd size (P=0.09) or region (P=0.43), but was different by sampling time period (P=0.004).

a. Number of cows tested for *E. coli,* and number and percentage of cows positive for *E. coli*, by size of operation

	Herd Size (number of beef cows)				
	1–49	**50–99**	**100–199**	**200 or more**	**Total**
Number tested	293	230	400	556	1,479
Number positive	242	157	298	450	1,147
Percent positive	82.6	68.3	74.5	80.9	77.6

b. Number of cows tested for *E. coli,* and number and percentage of cows positive for *E. coli*, by region

	Region			
	West	**Central**	**Southeast**	**Total**
Number tested	328	498	653	1,479
Number positive	245	373	529	1,147
Percent positive	74.7	74.9	81.0	77.6

c. Number of cows tested for *E. coli,* and number and percentage of cows positive for *E. coli*, by sampling period

	Sampling Period	
	January 14–April 15	**July 7–August 3**
Number tested	837	642
Number positive	602	545
Percent positive	71.9	84.9

Isolate characteristics—No resistance was detected among the *E.coli* isolates to amikacin, ceftriaxone, ciprofloxacin, naladixic acid, or trimethoprim/sulfamethoxazole. Less than 2 percent of the isolates were resistant to the remaining antibiotics, with the exception of sulfamethoxazole (6.7 percent), streptomycin (6.5 percent), and tetracycline (16.0 percent).

d. Percentage of resistant *E. coli* isolates, by antimicrobial

Antimicrobial	**Percent** (n=1,146)
Amikacin	0.0
Amoxicillin	0.3
Ampicillin	1.8
Cefoxitin	0.2
Ceftiofur	0.2
Ceftriaxone	0.0
Chloramphenicol	0.4
Ciprofloxacin	0.0
Gentamicin	0.3
Kanamycin	0.1
Nalidixic acid	0.0
Sulfamethoxazole	6.7
Tetracycline	16.0
Streptomycin	6.5
Trimethoprim-sulfamethoxazole	0.0
Any	16.6

Overall, 83.7 percent of the *E. coli* isolates were susceptible to all antibiotics in the panel tested. An additional 6.4 percent of isolates were resistant to only a single antibiotic. The remaining isolates were resistant to two antibiotics (4.6 percent) or three or more antibiotics (5.3 percent). The maximum number of antibiotics that any isolate was resistant to was six.

e. Number and percentage of isolates by number of antimicrobials to which antimicrobial resistance was observed

Number antimicrobials to which resistance was observed	Number isolates	Percent isolates
0	959	83.7
1	73	6.4
2	53	4.6
3 or more	61	5.3
Total	1,146	100.0

Summary—As expected for a commensal organism, *E. coli* was recovered from most of the samples cultured for *E. coli* (77.6 percent). Most of these isolates were susceptible to all antibiotics in the panel tested. None of these isolates had a resistance type that suggested they produced the extended spectrum beta lactamases that have been emerging in other areas of the world and can be associated with severe human illness. When resistance was present among the *E. coli* isolates, it was typically for older generation antibiotics (tetracycline, streptomycin, or sulfamethoxazole).

5. *Clostridium difficile*

Operation level prevalence—Overall 76 of 173 operations (43.9 percent) had at least one sample positive for *C. difficile*. There was no difference in the percentage of operations with positive samples by herd size (P=0.50). The percentage of operations with a sample positive for *C. difficile* differed by region (P=0.01).

a. Number of operations that tested samples for *Clostridium difficile,* and number and percentage of operations with at least one sample positive for *C. difficile*, by size of operation

	Herd Size (number of beef cows)				
	1–49	**50–99**	**100–199**	**200 or more**	**Total**
Number tested	49	26	42	56	173
Number positive	26	11	17	22	76
Percent positive	53.1	42.3	40.5	39.3	43.9

b. Number of operations that tested samples for *C. difficile,* and number and percentage of operations with at least one sample positive for *C. difficile*, by region

	Region			
	West	**Central**	**Southeast**	**Total**
Number tested	39	54	80	173
Number positive	11	21	44	76
Percent positive	28.2	38.9	55.0	43.9

c. Association between antibiotic-use practices and presence of *C. difficile* on the operations

Response	Herds positive	Herds negative	P-value
Antibiotic use in feed			
Any cattle or calves[1]			
Yes	23	35	0.42
No	53	62	
Antibiotic use—oral or injection			
Any cattle or calves[1]			
Yes	66	85	0.88
No	10	12	
Unweaned calves[2]			
Yes	47	61	0.89
No	29	36	
Replacement heifers[2]			
Yes	28	31	0.50
No	48	66	
Cows[2]			
Yes	40	44	0.34
No	36	53	

[1]Operation policy to use oral or injectable antibiotics to treat any animals.
[2]Treatment of one or more animals of the specified class with either oral or injectable antibiotics in 2007.

Sample-level prevalence—Overall, 186 of 2,922 of samples (6.4 percent) were positive for *C. difficile*. There was no difference in the percentage of positive cows by herd size (P=0.11), but there was a difference by region (P=0.01).

d. Number of cows tested for *C. difficile,* and number and percentage of cows positive for *C. difficile*, by size of operation

	Herd Size (number of beef cows)				
	1–49	**50–99**	**100–199**	**200 or more**	**Total**
Number tested	561	457	794	1,110	2,922
Number positive	44	32	65	45	186
Percent positive	7.8	7.0	8.2	4.1	6.4

e. Number of cows tested for *C. difficile,* and number and percentage of cows positive for *C. difficile*, by region

	Region			
	West	**Central**	**Southeast**	**Total**
Number tested	652	990	1,280	2,922
Number positive	17	43	126	186
Percent positive	2.6	4.3	9.8	6.4

Isolate characteristics—No *C. difficile* isolates were resistant to vancomycin. Very few isolates were resistant to amoxicillin-clavulanic acid or metronidazole (0.5 percent each). More than 90 percent of isolates were resistant to clindamycin and levofloxacin.

f. Number and percentage of resistant *C. difficile* isolates, by antimicrobial

Antimicrobial	Number isolates n=188)	Percent isolates
Linezolid	2	1.1
Amoxicillin-clavulanic acid	1	0.5
Ampicillin	29	15.6
Clindamycin	169	90.9
Erythromycin	6	3.2
Metronidazole	1	0.5
Levofloxacin	181	97.3
Rifampicin	27	14.5
Vancomycin	0	0

The highest percentage of isolates were resistant to two antibiotics, usually clindamycin and levofloxacin (62.4 percent).

g. Number and percentage of isolates by number of antimicrobials to which antimicrobial resistance was observed

Number of antimicrobials to which resistance was observed	Number isolates	Percent isolates
1	16	8.6
2	116	62.4
3	48	25.8
4	6	3.2
Total	186	100.0

Summary—C. difficile was found on less than half of the beef cow-calf operations tested and in less than 10 percent of the collected samples. Antibiotic-use practices were not associated with the ability to recover *C. difficile* on operations. Presence of *C. difficile* on operations was not associated with herd size but was associated with region, with the organism more likely to be identified from herds in the Southeast region. All *C. difficile* isolates were resistant to at least one antimicrobial. However, none of the *C. difficile* isolates was resistant to vancomycin, and 0.5 percent of isolates were resistant to metronidazole and amoxicillin-clavulanic acid. When treatment is used for human cases of *C. difficile*-associated disease, vancomycin and metronidazole are the antimicrobials most commonly used.

Future work to be accomplished for C. difficile—In 2004, an epidemic strain of *C. difficile* was identified that appears to be more virulent than other strains, as it has the ability to produce greater quantities of toxins A and B. In addition, it is more resistant to the antibiotic group known as fluoroquinolones. More advanced testing methods than were used in this report are needed to identify this epidemic strain. The techniques listed below will be used to further characterize *C. difficile* isolates from this study, and results from this testing will be reported at a later time.

1. Pulsed field gel electrophoresis (PFGE)
2. Toxinotyping
3. repPCR typing
4. Toxin gene assays
5. Toxin detection

Summary of operation culture status for organisms of interest based on operations characteristics

		Organism											
		Salmonella			*Campylobacter*			*Enterococcus*			*C. difficile*		
Operation characteristic	**Level**	**Pos**	**Neg**	**P-value**	**Pos**	**Neg**	**P-value**	**Pos**	**Neg**	**P-value**	**Pos**	**Neg**	**P-value**
Herd size (cows)													
	1-49	2	47	0.39	8	41	<0.0001	47	2	0.40	26	23	0.50
	50-99	2	24		10	16		26	0		11	15	
	100-199	6	36		23	19		41	1		17	25	
	200 or more	6	50		36	20		56	0		22	34	
		16	157		77	96		170	3		76	97	
Region													
	West	5	34	0.46	19	20	0.008	37	2	0.22	11	28	0.01
	Central	3	51		32	22		54	0		21	33	
	Southeast	8	72		26	54		79	1		44	36	
Antimicrobial use in feed													
	Yes	3	55	0.19	25	33	0.79	58	0	0.55	23	35	0.42
	No	13	102		52	63		112	3		53	62	
		16	157		77	96		170	3		76	97	
Antimicrobial use—oral or injection													
Any cattle or calves	Yes	14	137	1.0	69	82	0.41	148	3	1.0	66	85	0.88
	No	2	20		8	14		22	0		10	12	
		16	157		77	96		170	3		76	97	
Unweaned calves	Yes	9	99	0.59	53	55	0.12	106	2	1.0	47	61	0.89
	No	7	58		24	41		64	1		29	36	
		16	157		77	96		170	3		76	97	
Replacement heifers	Yes	6	53	0.76	29	30	0.38	58	1	1.0	28	31	0.50
	No	10	104		48	66		112	2		48	66	
		16	157		77	96		170	3		76	97	
Cows	Yes	8	76	0.90	43	41	0.09	84	0	0.25	40	44	0.34
	No	8	81		34	55		86	3		36	53	
		16	157		77	96		170	3		76	97	

Section IV: Methodology

A. Needs Assessment

The National Animal Health Monitoring System (NAHMS) develops study objectives by exploring existing literature and contacting stakeholders about their informational needs and priorities during a needs assessment phase. Stakeholders for NAHMS studies include industry members, allied industry representatives, other government agencies, animal health officials, and many others. The objective of the needs assessment for the NAHMS Beef 2007–08 study was to collect information about the most important health and productivity issues of cow-calf production. A driving force for the needs assessment was the desire of NAHMS to receive as much input as possible from a variety of producers, as well as from industry experts and representatives, veterinarians, extension specialists, universities, and beef organizations. Information was collected via interviews with key industry figures and through a Needs Assessment Survey.

The Needs Assessment Survey was designed to identify the most critical information gaps regarding animal health, and health and production management from producers, veterinarians, extension personnel, university researchers, and allied industry groups. The survey, created in SurveyMonkey, was available online from September 9, 2006, through February 15, 2007. The survey was promoted via electronic newsletters, magazines, and Web sites. Organizations/magazines promoting the study included "Beef Magazine," "Drovers," "Feedstuffs," "Bovine Veterinarian," and "The National Cattleman."

Email messages identifying the online site and asking for input were also sent to State extension personnel as well as State and Federal animal health officials. A total of 94 people completed the survey. Universities/extensions accounted for 41.5 percent of respondents, and veterinarians/consultants accounted for 31.9 percent.

Objectives for the Beef 2007–08 study, using input from interviews, literature searches, and the online survey, were drafted and circulated to stakeholder groups. Following this review, six final study objectives were identified:

1. Describe trends in beef cow-calf health and management practices.
2. Evaluate management factors related to beef quality assurance.
3. Describe record-keeping practices on cow-calf operations.
4. Determine producer awareness of bovine viral diarrhea (BVD) and management practices used for BVD control.
5. Describe current biosecurity practices.
6. Determine the prevalence and antimicrobial resistance patterns of potential food safety pathogens.

B. Sampling and Estimation

1. State selection

The preliminary selection of States to be included in the study was done in October 2006 using the National Agricultural Statistics Service (NASS) Cattle Report. A goal for NAHMS national studies is to include States that account for at least 70 percent of the animals and producer population in the United States. The initial review identified 24 States representing 87.8 percent of the Nation's beef-cow inventory and 79.6 percent of operations with beef cows (cow-calf herds). The States were: Alabama, Arkansas, California, Colorado, Florida, Georgia, Idaho, Iowa, Kansas, Kentucky, Louisiana, Mississippi, Missouri, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Tennessee, Texas, Virginia, and Wyoming.

A memo identifying the States was provided in November 2006 to the USDA–APHIS–VS CEAH Director and, in turn, the VS Regional Directors. Each Regional Director sought input from the respective States about being included or excluded from the study.

2. Operation selection

The list sampling frame was provided by NASS. Within each State a stratified random sample was selected. The size indicator was the number of beef cows for each operation. NASS selected a sample of beef producers in each State for making the January 1 cattle estimates. The list sample from the January 2007 survey was used as the screening sample. Those producers in the 24 States reporting 1 or more beef cows on January 1, 2007, were included in the sample for contact in October 2007.

3. Population selection

a. Phase I: General Beef Management Report; and Phase II: VS Initial and Second Visits

Inferences cover the population of beef producers with at least 1 beef cow in the 24 participating States. As of January 1, 2008, these States accounted for 79.6 percent (28.6 million) of beef cows and 79.6 percent (603,000) of operations with beef cows in the United States. (See Appendix III for respective data on individual States.) All respondent data were statistically weighted to reflect the population from which they were selected. The inverse of the probability of selection for each operation was the initial selection weight. This selection weight was adjusted for nonresponse within each State and size group to allow for inferences back to the original population from which the sample was selected.

C. Data and Sample Collection

1. Data collectors and data collection periods

a. Phase I: General Beef Management Report
From October 22 through November 30, 2007, NASS enumerators administered the General Beef Management Report. The interview took slightly over 1 hour.

b. Phase II: VS Initial Visit Questionnaire
From January 14 through March 31, 2008, State and Federal animal health personnel administered the Beef 2007–08 VS Initial Visit Questionnaire.

c. Phase II: VS Second Visit Questionnaire
From July 1 through August 15, 2008, State and Federal animal health personnel administered the Beef 2007–08 VS Second Visit Questionnaire.

2. Biological sample collection, culturing, and testing for antimicrobial resistance

A convenience sample of 175 operations was identified for collection of fecal samples from beef cows to evaluate enteric bacteria. The total number of operations was determined by laboratory capacity. Sample collection occurred over two sampling periods: January 14 through April 15, 2008, and July 7 through August 31, 2008. The number of operations in each State was determined according to the size of the beef cow population in the State. Operations were selected for sampling to be approximately representative of the distribution of herd sizes participating in the study. Up to 40 fecal samples of approximately 30 grams were collected per herd, depending on number of beef cows present. Samples were collected from fresh fecal pats from beef cows. Samples were shipped overnight on ice packs to a single laboratory for further processing.

Each sample was cultured for *Salmonella*. Every other sample was cultured for *Campylobacter*. Every fourth sample was cultured for *Escherichia coli*. Representative isolates from each culturing effort were evaluated for susceptibility to panels of antimicrobial drugs using a semi-automated microdilution testing system.

Isolates were further characterized by serotyping (*Salmonella*) or speciation (*Enterococcus, Campylobacter*).

D. Data Analysis

1. Phase I: Validation—General Beef Management Report

Initial data entry and validation for the General Beef Management Report were performed in individual NASS State offices. Data were entered into a SAS® data set. NAHMS national staff performed additional data validation on the entire data set after data from all States were combined.

2. Phase II: Validation—Initial and Second Visit Questionnaires

After completing both VS questionnaires, data collectors sent them to their respective State NAHMS Coordinators who reviewed the questionnaire responses for accuracy. Data entry and validation were completed by CEAH staff using SAS.

E. Sample Evaluation

The purpose of this section is to provide various performance measurement parameters. Historically, the term "response rate" was used as a catchall parameter, but there are many ways to define and calculate response rates. Therefore, the following table presents an evaluation based on a number of measurement parameters, which are defined with an "x" in categories that contribute to the measurement.

1. Phase I: General Beef Management Report

A total of 4,001 operations were selected for the survey. Of these operations, 3,648 (91.2 percent) were contacted. There were 2,872 operations that provided usable inventory information (71.8 percent of the total selected and 78.7 percent of those contacted.) In addition, there were 2,159 operations (54.0 percent of total selected) that provided "complete" information for the questionnaire. Of operations that provided complete information, 1,033 (47.8 percent) consented to be contacted for consideration/discussion about further participation in Phase II (VS collection) of the study.

Responses for Phase I: General Beef Management Report

			Measurement Parameter		
Response category	Number operations	Percent operations	Contacts	Usable[1]	Complete[2]
Survey complete and VMO consent	1,033	25.8	x	x	x
Survey complete, refused VMO consent	1,126	28.1	x	x	x
No beef cows on October 1 and July 1, 2007	469	11.7	x	x	
Out of business	244	6.1	x	x	
Out of scope (prison and research farms, etc.)	7	0.2			
Refusal of GBMR	776	19.4	x		
Office hold (NASS elected not to contact)	46	1.2			
Inaccessible	300	7.5			
Total	4,001	100.0	3,648	2,872	2,159
Percent of total operations			91.2	71.8	54.0
Percent of total operations weighted[3]			92.9	77.8	52.1

[1] Useable operation—respondent provided answers to inventory questions for the operation (either zero or positive number on hand).
[2] Survey complete operation—respondent provided answers to all or nearly all questions.
[3] Weighted response—the rate was calculated using the initial selection weights.

2. Phase II: VS Initial Visit

There were 1,033 operations that consented during Phase I to be contacted by a veterinary medical officer (VMO) for Phase II. Of these 1,033, 567 (54.9 percent) agreed to continue in Phase II of the study and completed the VMO Initial Visit Questionnaire; 365 (35.3 percent) refused to participate. Approximately 8 percent of the 1,033 operations were not contacted, and 2.0 percent were ineligible because they had no beef cows at the time they were contacted by the VMO during Phase II.

Responses for Phase II: VS Initial Visit

			Measurement Parameter		
Response category	Number operations	Percent operations	Contacts	Usable[1]	Complete[2]
Survey complete	567	54.9	x	x	x
Survey refused	365	35.3	x		
Not contacted	80	7.8			
Ineligible[3]	21	2.0	x	x	
Total	1,033	100.0	953	588	567
Percent of total operations			92.2	56.9	54.9
Percent of total operations weighted[4]			91.1	49.1	45.9

[1]Useable operation—respondent provided answers to inventory questions for the operation (either zero or positive number on hand).
[2]Survey complete operation—respondent provided answers to all or nearly all questions.
[3]Ineligible—no beef cows at time of interview, which occurred from January 14 through March 31, 2008.
[4]Weighted response—the rate was calculated using the turnover weights.

3. Phase II: VS Second Visit

There were 567 operations that completed the VS initial visit. Of these 567, 470 (82.9 percent) agreed to continue in Phase II of the study and completed the VMO Second Visit Questionnaire; 60 (10.6 percent) refused to participate. A total of 5.1 percent of the 567 operations were not contacted, and 1.2 percent were ineligible because they had no beef cows at the time they were contacted by the VMO during Phase II for the second visit.

Responses for Phase II: VS Second Visit

			Measurement Parameter		
Response category	Number operations	Percent operations	Contacts	Usable[1]	Complete[2]
Survey complete	470	82.9	x	x	x
Survey refused	60	10.6	x		
Not contacted	29	5.1			
Ineligible[3]	8	1.4	x	x	
Total	567	100.0	538	478	470
Percent of total operations			94.9	84.3	82.9
Percent of total operations weighted[4]			93.9	77.7	75.8

[1]Useable operation—respondent provided answers to inventory questions for the operation (either zero or positive number on hand).
[2]Survey complete operation—respondent provided answers to all or nearly all questions.
[3]Ineligible—no beef cows at time of interview, which occurred from July 1 through August 15, 2008.
[4]Weighted response—the rate was calculated using the turnover weights.

Appendix I: Sample Profile—Responding Operations

a. Number of responding operations, by herd size			
Herd size (total beef cow inventory)	**Phase I: General Beef Management Report**	**Phase II: VS Initial Visit**	**Enteric Bacteria Sampling**
1 to 49	819	163	49
50 to 99	386	96	26
100 to 199	381	125	42
200 or more	573	183	56
Total	2,159	567	173

b. Number of responding operations, by region			
Region	**Phase I: General Beef Management Report**	**Phase II: VS Initial Visit**	**Enteric Bacteria Sampling**
West	370	138	39
Central	612	196	54
South Central*	483	233	80
East*	694		
Total	2,159	567	173

* Regions were combined for VS portion of study.

Appendix II: Organism Overviews

1. *Salmonella*

Salmonella is a gram-negative, rod-shaped bacterium that can cause diarrheal illness in humans and animals. Humans often acquire *Salmonella* by eating foods contaminated with animal feces. Foodborne salmonellosis in the United States most commonly results from *Salmonella* serovars *enteritidis, Typhimurium*, and Newport (CDC, 2009c).

Salmonellae cause an estimated 1 million cases of foodborne illness in the United States each year and are estimated to result in 378 deaths annually (Scallan, 2011b). Symptoms of salmonellosis in humans generally occur within 8 to 72 hours following infection and include diarrhea, abdominal cramps, and fever. Chills, headache, nausea, and vomiting may also occur. Antibiotics may not eliminate the infection and may lead to resistant strains or more severe infections; therefore, antibiotic treatment is rarely warranted and most individuals recover without incident in 4 to 7 days. The disease can be life threatening, however, in infants under 2 months of age, the elderly, immune-suppressed individuals, and people with signs of extraintestinal infection. Treatment with ciprofloxacin is highly effective in adults. Antimicrobial resistance is variable and, when detected, TMP-SMX and chloramphenicol become appropriate alternatives (Chin, 2000).

Beef, poultry, milk, eggs as well as other foods such as produce can be contaminated with *Salmonella*. Contamination of meat more commonly results from contamination of carcasses with intestinal contents during slaughter (Todar, 2000). While *Salmonella* is occasionally found in raw milk, the pasteurization process effectively kills the organism. Cross-contamination of vegetables can also result in disease transmission via contact with juices from raw meat or poultry or contamination on the farm prior to harvesting.

Safe food-handling practices are paramount, as properly cooking meat and poultry kills the bacteria. Likewise, food containing raw eggs and unpasteurized milk should be avoided to reduce the risk of salmonellosis. Sporadic cases of salmonellosis also occur following exposure to the feces of an infected pet or handling of reptiles that commonly harbor salmonellae (CDC, 2009c).

2. *Campylobacter*

Campylobacter spp. are estimated to cause approximately 850,000 cases of gastroenteritis each year in the United States, 80 percent of which are food related, resulting in 76 deaths annually (Scallan, 2011b).

The infective dose, or bacterial load sufficient to cause disease in susceptible individuals, is less than 500 organisms. Infection can cause diarrhea, cramping, abdominal pain, and fever within 2 to 5 days after exposure. The diarrhea may be bloody and associated with nausea and vomiting as well. The infection is generally self limiting and will resolve in 7 to 10 days without antibiotics, although treatment with erythromycin will decrease the amount of time the organism is shed (Chin, 2000). Rarely, affected individuals will develop arthritis or Guillain-Barré syndrome as a sequela to infection in which the immune system attacks the body's own nerves (CDC, 2009a).

Campylobacter is a gram-negative, slender, curved, and motile rod. The bacterium is microaerophilic, meaning it requires an environment with reduced levels of oxygen.

Organisms of the genus *Campylobacter* are commonly found in the intestinal tract of companion and food animals. Disease in humans most often occurs following exposure to raw or undercooked poultry meat (Corry and Atabay, 2001). *C. jejuni* is most often responsible for disease in humans, but rarely causes disease in birds due to their elevated body temperatures.

Campylobacter rarely causes gastrointestinal disease in cattle but is commonly harbored in the intestinal tract of up to 9 percent of cattle, *C. jejuni* more so than *C. coli* (Wesley et al., 2000). Fecal contamination of carcasses at slaughter yields potential for foodborne transmission, although the organism is rarely isolated from such sources (Hakkinen et al., 2007). *Campylobacter* is rarely associated with outbreaks; sporadic, single cases are much more common. Outbreaks have occurred in the past, however, and are usually related to contaminated dairy products (Schildt et al., 2005). Unpasteurized milk and contaminated water also can result in outbreaks of campylobacteriosis.

3. *Clostridium difficile*

Clostridium difficile is a bacterial organism capable of producing a toxin-causing diarrheal disease in humans and food animals. Traditionally, the disease in humans has been acquired in hospital settings (Kuijper et al., 2006), more commonly in individuals with prolonged hospitalization, greater than 65 years of age, and antibiotic exposure (McDonald et al., 2006). However, changes have been observed in the epidemiology of the pathogen, and what were previously classified as low-risk individuals are succumbing to disease (Chernakl et al., 2005). Furthermore, *C. difficile* has been recognized as an emerging animal pathogen (Songer and Anderson, 2006).

Molecular testing has been used to classify strains of *C. difficile* and has demonstrated that the prevalence of strains with the binary toxin gene could indicate that animal and human reservoirs have begun to overlap in recent years (Rupnik, 2007). Also, nearly 30 percent of retail ground-meat products are reported to be positive for the organism (Rodriguez-Palacio et al., 2007). Of note, *C. difficile* spores in contaminated meats are not completely destroyed via cooking, suggesting that all meat products, including ready-to-eat foods, may act as a potential source of foodborne transmission of *C difficile* to humans.

C. difficile is a spore-forming, gram-positive, anaerobic bacillus that produces a number of different exotoxins resulting in gastrointestinal infections in humans and animals. In recent years, reports indicate that *C. difficile*-associated disease has increased in terms of rates and severity of disease (Jhung et al., 2008), which has also led to a heightened public health concern over the disease. *C. difficile* infection in humans results in watery diarrhea consisting of three or more bowel movements per day for 2 or more days, fever, loss of appetite, nausea, and abdominal pain. The disease generally responds to 10-day treatments with metronidazole or vancomycin (Johnson and Gerding, 1998).

4. Commensal *Escherichia coli*

Commensal *Escherichia coli* are normal inhabitants of the gastrointestinal tract of livestock and humans and do not typically cause disease. Shiga toxin-producing *E. coli*, of which O157:H7 is included, rarely causes clinical disease in cattle but can cause food-related outbreaks of gastrointestinal disease in humans (CDC, 2009b). Antimicrobial resistance remains a concern in commensal *E. coli* of cattle and other food animals due to the potential transfer of resistance elements to zoonotic pathogens inhabiting the gut (Sharma et al, 2008). Commensal *E. coli* is also important as it is often used as an indicator organism to assess the extent and type of resistance in the gastrointestinal tract, since it plays a dynamic role in the ecology of multidrug-resistant bacteria and has shown to be a reservoir of resistance (Carson et al, 2001).

Appendix III: Number of Beef Cows, by Region

Number of Beef Cows on January 1, 2008*			
Region	**State**	**Beef cow inventory Jan. 1, 2008** (Thousand Head)	**Beef cow operations 2007**
West	California	655	11,200
	Colorado	730	9,900
	Idaho	460	7,100
	Montana	1,523	11,000
	New Mexico	460	5,900
	Oregon	605	11,500
	Wyoming	733	4,800
	Total	5,166	61,400
Central	Iowa	1,015	25,000
	Kansas	1,511	26,000
	Missouri	2,080	54,000
	Nebraska	1,883	20,000
	North Dakota	922	10,500
	South Dakota	1,644	14,500
	Total	9,055	150,000
Southeast	Alabama	677	23,000
	Arkansas	943	26,000
	Florida	936	15,500
	Georgia	553	17,500
	Kentucky	1,159	38,000
	Louisiana	513	12,100
	Mississippi	519	18,500
	Oklahoma	2,053	48,000
	Tennessee	1,079	42,000
	Texas	5,240	130,000
	Virginia	692	21,000
	Total	14,364	391,600
Total (24 States)		28,585	603,000
Percentage of U.S.		87.8	79.6
Total U.S. (50 States)		32,553	757,900

*Source: NASS Cattle report, February 1, 2008, and NASS Farms, Land in Farms, and Livestock Operations 2007 Summary report, February 2008. An operation is any place having one or more head of beef cows, excluding cows used to nurse calves, on hand at any time during the year.

Appendix IV: American Veterinary Medical Association Judicious Use Principles

American Veterinary Medical Association Position Statement[1]

"When the decision is reached to use antimicrobials for therapy, veterinarians should strive to optimize therapeutic efficacy and minimize resistance to antimicrobials to protect public and animal health."

AVMA Judicious Use Principles

- Preventive strategies, such as appropriate husbandry and hygiene, routine health monitoring, and immunization, should be emphasized.
- Other therapeutic options should be considered prior to antimicrobial therapy.
- Judicious use of antimicrobials, when under the direction of a veterinarian, should meet all requirements of a veterinarian-client-patient relationship.
- Prescription, Veterinary Feed Directive, and extralabel use of antimicrobials must meet all the requirements of a veterinarian-client-patient relationship.

Extralabel antimicrobial therapy must be prescribed only in accordance with the Animal Medicinal Drug Use Clarification Act amendments to the Food, Drug, and Cosmetic Act and its regulations.

Veterinarians should work with those responsible for the care of animals to use antimicrobials judiciously regardless of the distribution system through which the antimicrobial was obtained.

Regimens for therapeutic antimicrobial use should be optimized using current pharmacological information and principles.

Antimicrobials considered important in treating refractory infections in human or veterinary medicine should be used in animals only after careful review and reasonable justification. Consider using other antimicrobials for initial therapy.[2]

Use narrow spectrum antimicrobials whenever appropriate.

Utilize culture and susceptibility results to aid in the selection of antimicrobials when clinically relevant.

Therapeutic antimicrobial use should be confined to appropriate clinical indications. Inappropriate uses such as for uncomplicated viral infections should be avoided.

Therapeutic exposure to antimicrobials should be minimized by treating only for as long as needed for the desired clinical response. Limit therapeutic antimicrobial treatment to ill or at risk animals, treating the fewest animals indicated.

Minimize environmental contamination with antimicrobials whenever possible.

Accurate records of treatment and outcome should be used to evaluate therapeutic regimens.

[1] AVMA, 2008.

[2] In this context, this principle takes into account development of resistance or cross-resistance to important antimicrobials.

Appendix V: AABP Revised Prudent Drug Usage Guidelines

The production of safe and wholesome animal products for human consumption is a primary goal of members of the AABP. In reaching that goal, the AABP is committed to the practice of preventive immune system management through the use of vaccines, parasiticides, stress reduction and proper nutritional management. The AABP recognizes that proper and timely management practices can reduce the incidence of disease and therefore reduce the need for antimicrobials.

Nevertheless, antimicrobials remain a necessary tool to manage infectious diseases in beef and dairy herds. Prudent use of antimicrobials is necessary to reduce animal pain and suffering, to protect the economic livelihood of beef and dairy producers, to ensure the continued production of foods of animal origin, and to minimize the shedding of zoonotic bacteria into the environment and potentially the food chain. Following are general guidelines for the prudent use of antimicrobials in beef and dairy cattle.

1. The veterinarian's primary responsibility to the client is to help design management, immunization, housing and nutritional programs that will reduce the incidence of disease and the need for antimicrobials.
2. Antimicrobials should be used only within the confines of a valid veterinarian-client-patient relationship; this includes both dispensing and the issuance of prescriptions. Extra-label usage should be within the provisions contained within the AMDUCA regulations.
3. The veterinarian should have strong clinical evidence of the identity of the pathogen causing the disease, based upon clinical signs, history, necropsy examination, laboratory data and past experience. He/she should periodically monitor herd pathogen susceptibility and therapeutic response to detect changes in microbial susceptibility and to re-evaluate antimicrobial selections.
4. Product choices and regimens should be based on available laboratory and package insert information, additional data in the literature and consideration of the pharmacokinetics, spectrum and pharmacodynamics of the drug. Antimicrobials should be used with a specific clinical outcome(s) in mind, such as fever reduction or return of mastitic milk to normal.
5. Antimicrobials should be used at a dosage and duration appropriate for the condition treated. The goals of therapy should be to alleviate clinical signs and minimize recurrence of clinical disease.
6. Treatment of chronic cases should be avoided if the likelihood of antimicrobial resistance outweighs the chances of pathogen elimination. Chronic cases should be removed or isolated from the remainder of the herd to minimize disease spread within the herd.
7. When appropriate, local therapy (e.g. intramammary, intrauterine, topical) is preferred over systemic therapy.

8. Combination antimicrobial therapy should be discouraged unless there is information to show an increase in efficacy or suppression of resistance development for the target organism.
9. Prophylactic or metaphylactic use of antimicrobials should be based on a group, source or production unit evaluation rather than standard practice.
10. Compounding of antimicrobial formulations should be avoided unless science based pharmacokinetic and pharmacodynamic data to support the use of such products are available.
11. Quantities of antimicrobials prescribed or dispensed should be appropriate in order to avoid stockpiling of antimicrobials on the farm.
12. Veterinarians should participate in continuing education programs regarding emergence and/or development of antimicrobial resistance and prudent drug usage. Whenever possible, veterinarians are encouraged to utilize this information to provide written guidelines that describe conditions and instructions for antimicrobial use at each farm or unit.
13. Veterinarians should play a major role in training farm personnel who use antimicrobials on diagnosis of common diseases, indications for antimicrobial use, dosage, withdrawal times, route of administration, injection site precautions, storage, handling and record keeping.

Guidelines 1-13 adapted from American Veterinary Medical Association, American Association of Bovine Practitioners, and Academy of Veterinary Consultants Appropriate Veterinary Antibiotic Use Guidelines.

Appendix VI: References

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