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FOOD SECURITY, SAFE FOOD, AND ANIMAL HEALTH

NON-TECHNICAL SUMMARY: The challenge to U.S. and global food and fiber animal agricultural systems is to balance the imperative to produce a safe, affordable, abundant, and wholesome food with the economic need to sustain the producer and the societal desire to develop sustainable systems. This project addresses these issues by addressing important food safety concerns with pathogens, and antibiotic resistance, economics of agricultural systems, and the application of new technology and approaches to optimize production systems, minimize environmental impacts, and training of veterinarians and producers to understand the implications of new systems. The research is conducted on population and molecular scales and include the advancement of basic knowledge as well as applied knowledge.

OBJECTIVES: The goals of this project are: Support the availability, affordability, and sustainability of livestock source foods and improve animal and public health. The project objectives are:1. Describe the pathophysiology and ecology of major zoonotic food and waterborne pathogens with a primary focus on defining properties associated with dissemination and developing interventions to change transmission frequency between animals and people.2. Develop systems and processes that change the dynamics of on farm antibiotic resistance.3. Focus on the major dairy cattle mastitis pathogens, particularly Mycoplasma and Staphylococcus, to determine population structure and identify strategies to mitigate their impact on milk quality.4. Develop and implement process control and complementary record systems on dairy systems and assess their efficacy as tools for improving animal health and production.

APPROACH: The approaches and methods for addressing the project objectives are grounded in field sampling and working with practitioners and producers. A primary resource for much of this work is the extensive database and samples continuously collected and stored in Field Disease Investigation Unit freezers. These existing samples are catalogued, curated, and available to all investigators involved with this project. Additional databases are also maintained by individual investigators and represent unique global-based isolates that can be used for comparative analyses. In addition, this project relies on a history of working with and for the animal industries which allows investigators access to sample on farms and develop on farm clinical trials. The research group also has a long standing relationship with both the state of Washington's

Department of Public Health and the Washington Animal Disease Diagnostic Laboratory which also provides access to field samples and isolates. The research incorporates both genotypic and phenotypic characterization of isolates including whole genome sequencing, SNP analyses, target gene analyses as well as phenotype data describing antibiotic resistance to create comprehensive descriptions of bacterial isolates. These data will be incorporated into sophisticated ecological and statistical modeling to assess and categorize population structures and discern transmission pathways. This includes adapting traditional statistical approaches, i.e. regression techniques, principal components, latent models, and adapting them to ecological and mathematical models. Another element of this project's research is to understand the human element involved with managing the on-farm processes for disease control and pathogen dissemination. The research procedures include developing tools that can be implemented on farm by employees to effectively capture health and process records and turn that data into feedback and feedforward information to improve on-farm efficiency. This research will explore different information technologies to both receive and disseminate these data.

KEYWORDS: animal agriculture, food systems, antibiotic resistance, Salmonella, STEC, mastitis, animal health

PROGRESS: 2016/10 TO 2017/09

Target Audience: Audience reached: veterinary students, undergraduate students, dairy producers, dairy veterinarians, dairy workers, scientists. Efforts included small audience presentations, direct interaction with producers, workers and veterinarians, scientific presentations, mentoring of veterinary and undergraduate students. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? All members of the project are actively involved in the training of professional DVM, graduate and undergraduate students. We include them in both laboratory and field research as well as in outreach efforts. How have the results been disseminated to communities of interest? The primary way that results are disseminated are through peer review publications. Additional dissemination occurs during field work and interactions with producers, workers, and veterinarians. We also actively develop materials working with our extension group via web pages, fact sheets, and in-person meetings. What do you plan to do during the next reporting period to accomplish the goals? Research projects are ongoing and expected to produce similar results as reported in this document.

IMPACT: 2016/10 TO 2017/09

What was accomplished under these goals? This project has impacts along the food production system continuum from the decisions on how and when to use an antibiotic, the design and use of facilities, inputs that augment calf health, and novel mitigation strategies to address on-farm ecology of animal health and food safety pathogens. Specifically, investigators have worked closely with dairy producers to enhance training for on-farm employees and helped to develop tools that improve calf and adult health. Investigators have also improved our understanding of the ecology of antimicrobial resistance and also mechanisms of action of non-antibiotic therapies to address disease in food production. Our group has worked with dairy cattle, poultry, and domestic sheep and investigated food safety issues as well as wildlife interface issues. While not directly outlined in this project, all participants in this project recognize the importance of community outreach via extension and believe it is a component of the proposed work to transfer knowledge via publications, electronic media, and through interaction with producers and veterinarians and to test the effectiveness of this outreach. All faculty are involved in outreach to our audiences and participated in the development of materials that are available through our WSU extension web pages.

PUBLICATIONS(not previously reported): 2016/10 TO 2017/09

1. Type: Journal Articles Status: Published Year Published: 2017 Citation: Sischo WM, Short DM, Geissler M, et al. Comparative composition, diversity, and abundance of oligosaccharides in early lactation milk from commercial dairy and beef cows. *J Dairy Sci* 2017.
2. Type: Journal Articles Status: Published Year Published: 2017 Citation: Carroll LM, Wiedmann M, den Bakker H, Siler J, Warchocki S, Kent D, Lyalina S, Davis M, Sischo W, Besser T, Warnick LD, Pereira RV. Whole-Genome Sequencing of Drug-Resistant *Salmonella enterica* Isolates from Dairy Cattle and Humans in New York and Washington States Reveals Source and Geographic Associations. *Appl Environ Microbiol* 2017;83.
3. Type: Journal Articles Status: Published Year Published: 2017 Citation: Mandel C, Adams-Progar A, Sischo WM, et al. Short communication: Predictors of time to dairy calf bucket training. *J Dairy Sci* 2017;100:9769-9774.
4. Type: Journal Articles Status: Published Year Published: 2017 Citation: Shah DH, Paul NC, Sischo WC, et al. Population dynamics and antimicrobial resistance of the most prevalent poultry-associated *Salmonella* serotypes. *Poult Sci* 2017;96:687-702.
5. Type: Journal Articles Status: Published Year Published: 2017 Citation: Plowright RK, Manlove KR, Besser TE, et al. Age-specific infectious period shapes dynamics of pneumonia in bighorn sheep. *Ecol Lett* 2017;20:1325-1336.
6. Type: Journal Articles Status: Published Year Published: 2017 Citation: Falghoush A, Beyenal H, Besser TE, et al. Osmotic Compounds Enhance Antibiotic Efficacy against *Acinetobacter baumannii* Biofilm Communities. *Appl Environ Microbiol* 2017;83.
7. Type: Journal Articles Status: Published Year Published: 2017 Citation: Zhao Z, Orfe LH, Liu J, Lu SY, Besser TE, Call DR. Microcin PDI regulation and proteolytic cleavage are unique among known microcins. *Sci Rep* 2017;7:42529.
8. Type: Journal Articles Status: Published Year Published: 2017 Citation: Roug A, Diaz-Campos D, Teitzel C, Besser TE. Comparison of Two Bacterial Transport Media for Culture of Tonsillar Swabs from Bighorn Sheep (*Ovis canadensis*) and Mountain Goats (*Oreamnos americanus*). *Journal of wildlife diseases* 2017;53:188-192.
9. Type: Journal Articles Status: Published Year Published: 2017 Citation: Roulette CJ, Caudell MA, Roulette JW, Quinlan RJ, Quinlan MB, Subbiah M, Call DR. A two-month follow-up evaluation testing interventions to limit the emergence and spread of antimicrobial resistant bacteria among Maasai of northern Tanzania. *BMC infectious diseases* 2017;17:770.
10. Type: Journal Articles Status: Published Year Published: 2017 Citation: Omulo S, Thumbi SM, Lockwood S, Verani JR, Bigogo G, Masyongo G, Call DR. Evidence of superficial knowledge regarding antibiotics and their use: Results of two cross-sectional surveys in an urban informal settlement in Kenya. *PLoS One* 2017;12:e0185827.2017;12:e0185827.
11. Type: Journal Articles Status: Published Year Published: 2017 Citation: Mosites E, Sammons M, Otiang E, Eng A, Noecker C, Manor O, Hilton S, Thumbi SM, Onyango C, Garland-Lewis G, Call DR, Njenga MK, Wasserheit JN, Zambriski JA, Walson JL, Palmer GH, Montgomery J, Borenstein E, Omoro R, Rabinowitz PM. Microbiome sharing between children, livestock and household surfaces in western Kenya. *PLoS One* 2017;12:e0171017.
12. Type: Journal Articles Status: Published Year Published: 2017 Citation: Caudell MA, Quinlan MB, Subbiah M, Call DR, Roulette CJ, Roulette JW, Roth A, Matthews L, Quinlan RJ. Antimicrobial Use and Veterinary Care among Agro-Pastoralists in Northern Tanzania. *PLoS One* 2017;12:e0170328.
13. Type: Journal Articles Status: Published Year Published: 2017 Citation: Caudell MA, Quinlan MB, Quinlan RJ, Call DR. Medical pluralism and livestock health: ethnomedical and biomedical veterinary knowledge among East African agropastoralists. *Journal of ethnobiology and ethnomedicine* 2017;13:7.
14. Type: Journal Articles Status: Published Year Published: 2017 Citation: Kiamco MM, Atci E, Mohamed A, Call DR, Beyenal H. Hyperosmotic Agents and Antibiotics Affect Dissolved Oxygen

and pH Concentration Gradients in Staphylococcus aureus Biofilms. Appl Environ Microbiol 2017;83.

15. Type: Journal Articles Status: Published Year Published: 2017 Citation: Lu SY, Zhao Z, Avillan JJ, Liu J, Call DR. Autoinducer-2 Quorum Sensing Contributes to Regulation of Microcin PDI in Escherichia coli. Front Microbiol 2017;8:2570.

16. Type: Journal Articles Status: Published Year Published: 2017 Citation: Omulo S, Lofgren ET, Mugoh M, Alando M, Obiya J, Kipyegon K, Kikwai G, Gumbi W, Kariuki S, Call DR. The impact of fecal sample processing on prevalence estimates for antibiotic-resistant Escherichia coli. J Microbiol Methods 2017;136:71-77.

17. Type: Journal Articles Status: Published Year Published: 2017 Citation: Zhao Z, Liu J, Deng Y, Huang W, Ren C, Call DR, Hu C. The Vibrio alginolyticus T3SS effectors, Val1686 and Val1680, induce cell rounding, apoptosis and lysis of fish epithelial cells. Virulence 2017:0.

18. Type: Journal Articles Status: Published Year Published: 2017 Citation: Sanjaya A, Elder JR, Shah DH. Identification of new CpG oligodeoxynucleotide motifs that induce expression of interleukin-1beta and nitric oxide in avian macrophages. Vet Immunol Immunopathol 2017;192:1-7.

19. Type: Journal Articles Status: Published Year Published: 2017 Citation: Paul NC, Sullivan TS, Shah DH. Differences in antimicrobial activity of chlorine against twelve most prevalent poultry-associated Salmonella serotypes. Food microbiology 2017;64:202-209.

20. Type: Journal Articles Status: Published Year Published: 2017 Citation: Adkins PRF, Middleton JR, Calcutt MJ, Stewart GC, Fox LK. Species Identification and Strain Typing of Staphylococcus agnetis and Staphylococcus hyicus Isolates from Bovine Milk by Use of a Novel Multiplex PCR Assay and Pulsed-Field Gel Electrophoresis. J Clin Microbiol 2017;55:1778-1788.

PROGRESS: 2015/10/01 TO 2016/09/30

Target Audience: Scientists, producers, lay audience, graduate students Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Professional, Graduate and undergraduate students and post doctoral scholars worked with faculty supported by this project. Provided them opportunities to develop research skills. How have the results been disseminated to communities of interest? All field based projects report results and conclusions to veterinarians and producers. Research supported by this project are reported out to the public through WSU extension newsletters. The primary dissemination is through peer-review publications. What do you plan to do during the next reporting period to accomplish the goals? Project will continue in the next year.

IMPACT: 2015/10/01 TO 2016/09/30

What was accomplished under these goals? 1. Describe and evaluate motivation and reward models for livestock care; specifically for managing animal health and treatment, 2. Develop strategies for managing work and providing feedback to workers, managers, and consultants responsible for animal health; 3. Evaluate the genetic and phenotypic variability of foodborne pathogens, with an emphasis on SE, Salmonella sp., and STEC, mastitis pathogens, and apply this knowledge to develop dissemination models, 4. Evaluate the use of non-antibiotic alternatives in calf rearing to prevent disease, reduce antibiotic use, and lower prevalence of antibiotic resistant organisms and traits. 5. Determine and model the impact of antibiotic use and excreted residues on the ecology of resistance traits and organisms and understand ecology using field-based research, and test mitigation strategies. 6. Evaluate the genomic diversity of mastitis pathogens and the impact of management strategies on this diversity; and 7. Develop and evaluate communication approaches based on different media including social networks (real and virtual) to broadcast project results to varied local and national audiences that include producers, calf caretakers, veterinarians and Extension educators.

PUBLICATIONS: 2015/10/01 TO 2016/09/30

1. Type: Journal Articles Status: Published Year Published: 2016 Citation: Moore DA, Smith DR, Sicho WM, Heaton K, Besser TE. *Escherichia coli* O157:H7--Discerning Facts from Fiction: An Integrated Research and Extension Project for Multiple Audiences. *Zoonoses Public Health*. 2016 Feb;63(1):72-81. doi: 10.1111/zph.12206.
2. Type: Journal Articles Status: Published Year Published: 2016 Citation: Raghavan B, Erickson K, Kugadas A, Batra SA, Call DR, Davis MA, Foreyt WJ, Srikumaran S. Role of carriers in the transmission of pneumonia in bighorn sheep (*Ovis canadensis*). *Biol Open*. 2016 Jun 15;5(6):745-55. doi: 10.1242/bio.018234
3. Type: Journal Articles Status: Published Year Published: 2016 Citation: Subbiah M, Mitchell SM, Call DR. Not All Antibiotic Use Practices in Food-Animal Agriculture Afford the Same Risk. *J Environ Qual*. 2016 Mar;45(2):618-29. doi: 10.2134/jeq2015.06.0297
4. Type: Journal Articles Status: Published Year Published: 2016 Citation: Ahmed S, Besser TE, Call DR, Weissman SJ, Jones LP, Davis MA. Evaluation of two multi-locus sequence typing schemes for commensal *Escherichia coli* from dairy cattle in Washington State. *J Microbiol Methods*. 2016 May;124:57-61. doi: 10.1016/j.mimet.2016.03.008.
5. Type: Journal Articles Status: Published Year Published: 2016 Citation: Liu J, Zhao Z, Orfe L, Subbiah M, Call DR. Soil-borne reservoirs of antibiotic-resistant bacteria are established following therapeutic treatment of dairy calves. *Environ Microbiol*. 2016 Feb;18(2):557-64. doi: 10.1111/1462-2920.13097.
6. Type: Journal Articles Status: Published Year Published: 2016 Citation: Lyimo B, Buza J, Subbiah M, Smith W, Call DR. Comparison of antibiotic resistant *Escherichia coli* obtained from drinking water sources in northern Tanzania: a cross-sectional study. *BMC Microbiol*. 2016 Nov 3;16(1):254.
7. Type: Journal Articles Status: Published Year Published: 2016 Citation: Schmidt CE, Shringi S, Besser TE. Protozoan Predation of *Escherichia coli* O157:H7 Is Unaffected by the Carriage of Shiga Toxin-Encoding Bacteriophages. *PLoS One*. 2016 Jan 29;11(1):e0147270. doi: 10.1371/journal.pone.0147270.
8. Type: Journal Articles Status: Published Year Published: 2016 Citation: Shah DH, Paul NC, Sicho WC, Crespo R, Guard J. Population dynamics and antimicrobial resistance of the most prevalent poultry-associated *Salmonella* serotypes. *Poult Sci*. 2016 Sep 24. pii: pew342. [Epub ahead of print
9. Type: Journal Articles Status: Published Year Published: 2016 Citation: Elder JR, Chiok KL, Paul NC, Haldorson G, Guard J, Shah DH. The *Salmonella* pathogenicity island 13 contributes to pathogenesis in streptomycin pre-treated mice but not in day-old chickens. *Gut Pathog*. 2016 May 2;8:16. doi: 10.1186/s13099-016-0098-0. Erratum in: *Gut Pathog*. 2016;8:35
10. Type: Journal Articles Status: Published Year Published: 2016 Citation: Afema JA, Byarugaba DK, Shah DH, Atukwase E, Nambi M, Sicho WM. Potential Sources and Transmission of *Salmonella* and Antimicrobial Resistance in Kampala, Uganda. *PLoS One*. 2016 Mar 21;11(3):e0152130. doi: 10.1371/journal.pone.0152130.
11. Type: Journal Articles Status: Published Year Published: 2016 Citation: Enger BD, White RR, Nickerson SC, Fox LK. Identification of factors influencing teat dip efficacy trial results by meta-analysis. *J Dairy Sci*. 2016 Dec;99(12):9900-9911. doi: 10.3168/jds.2016-11359
12. Type: Journal Articles Status: Published Year Published: 2016 Citation: Nicholas RA, Fox LK, Lysnyansky I. *Mycoplasma mastitis* in cattle: To cull or not to cull. *Vet J*. 2016 Oct;216:142-7. doi: 10.1016/j.tvjl.2016.08.001.
13. Type: Journal Articles Status: Published Year Published: 2016 Citation: Adkins PR, Middleton JR, Fox LK. Comparison of Virulence Gene Identification, Ribosomal Spacer PCR, and Pulsed-Field Gel Electrophoresis for Typing of *Staphylococcus aureus* Strains Isolated from Cases of Subclinical Bovine Mastitis in the United States. *J Clin Microbiol*. 2016 Jul;54(7):1871-6. doi: 10.1128/JCM.03282-15

14. Type: Journal Articles Status: Published Year Published: 2016 Citation: Fox LK. Short communication: Removal of hair from the mammary gland: Recovery of bacteria from teat skin and milk. *J Dairy Sci.* 2016 Feb;99(2):1461-4. doi: 10.3168/jds.2015-10099.
15. Type: Journal Articles Status: Published Year Published: 2016 Citation: Floren HK, Sischo WM, Crudo C, Moore DA. Technical note: Use of a digital and an optical Brix refractometer to estimate total solids in milk replacer solutions for calves. *J Dairy Sci.* 2016 Sep;99(9):7517-22. doi: 10.3168/jds.2015-10834
16. Type: Journal Articles Status: Published Year Published: 2016 Citation: Short DM, Moore DA, Sischo WM. A Randomized Clinical Trial Evaluating the Effects of Oligosaccharides on Transfer of Passive Immunity in Neonatal Dairy Calves. *J Vet Intern Med.* 2016 Jul;30(4):1381-9. doi: 10.1111/jvim.13949
17. Type: Journal Articles Status: Published Year Published: 2016 Citation: Moore DA, Sischo WM, Kurtz S, Siler JD, Pereira RV, Warnick LD, Davis MA. Improving Dairy Organizational Communication from the Veterinarian's Perspective: Results of a Continuing Veterinary Medical Education Pilot Program. *J Vet Med Educ.* 2016 Spring;43(1):33-40. doi: 10.3138/jvme.0215-028R.

PROGRESS: 2014/10/09 TO 2015/09/30

Target Audience: Food animal producers, veterinarians, public health practitioners, policy 'makers'.
Changes/Problems: Nothing Reported
What opportunities for training and professional development has the project provided? Primary training for 4 graduate students and one post-doctoral researcher. How have the results been disseminated to communities of interest? Participants publish and present papers to the general scientific community. We also participate in veterinary and producer continuing education. We supervise high school science projects related to the project and include veterinary students in projects. We work closely with cooperating producers and workers to review data collected from their farm. What do you plan to do during the next reporting period to accomplish the goals? These projects are ongoing.

IMPACT: 2014/10/09 TO 2015/09/30

What was accomplished under these goals? 1. Describe and evaluate motivation and reward models for livestock care; specifically for managing animal health and treatment, 2. Develop strategies for managing work and providing feedback to workers, managers, and consultants responsible for animal health; 3. Evaluate the genetic and phenotypic variability of foodborne pathogens, with an emphasis on SE, Salmonella sp., and STEC, and apply this knowledge to develop dissemination models, 4. Evaluate the use of non-antibiotic alternatives in calf rearing to prevent disease, reduce antibiotic use, and lower prevalence of antibiotic resistant organisms and traits. 5. Determine and model the impact of antibiotic use and excreted residues on the ecology of resistance traits and organisms and test mitigation strategies. 6. Evaluate the genomic diversity of mastitis pathogens and the impact of management strategies on this diversity; and 7. Develop and evaluate communication approaches based on different media including social networks (real and virtual) to broadcast project results to varied local and national audiences that include producers, calf caretakers, veterinarians and Extension educators.

PUBLICATIONS: 2014/10/09 TO 2015/09/30

1. Type: Journal Articles Status: Published Year Published: 2015 Citation: Alabdullah, H. A., L. K. Fox, J. M. Gay, G. M. Barrington, and R. H. Mealey. 2015. Effects of dexamethasone and *Mycoplasma bovis* on bovine neutrophil function in vitro. *Vet. Immunol. Immunopathol.* 164(1-2):67-73.
2. Type: Journal Articles Status: Published Year Published: 2015 Citation: Davis, M. A., W. M. Sischo, L. P. Jones, D. A. Moore, S. Ahmed, D. M. Short, and T. E. Besser. 2015. Recent Emergence of *Escherichia coli* with Cephalosporin Resistance Conferred by blaCTX-M on Washington State Dairy Farms. *Appl. Environ. Microbiol.* 81(13):4403-4410.

3. Type: Journal Articles Status: Published Year Published: 2015 Citation: Afema, J. A., A. E. Mather, and W. M. Sisco. 2015. Antimicrobial Resistance Profiles and Diversity in Salmonella from Humans and Cattle, 2004-2011. *Zoonoses. Public Health.* 62(7):506-517.
 4. Type: Journal Articles Status: Published Year Published: 2015 Citation: Adesoji, A. T., A. A. Ogunjobi, I. O. Olatoye, and D. R. Call. 2015. Prevalence of tetracycline resistance genes among multi-drug resistant bacteria from selected water distribution systems in southwestern Nigeria. *Ann. Clin. Microbiol. Antimicrob.* 14:35. doi: 10.1186/s12941-015-0093-1.:35-0093.
 5. Type: Journal Articles Status: Published Year Published: 2015 Citation: Enger, B. D., L. K. Fox, J. M. Gay, and K. A. Johnson. 2015. Reduction of teat skin mastitis pathogen loads: differences between strains, dips, and contact times. *J Dairy Sci.* 98(2):1354-1361.
 6. Type: Journal Articles Status: Published Year Published: 2015 Citation: Guard, J., R. Sanchez-Ingunza, D. H. Shah, M. J. Rothrock, R. K. Gast, and D. R. Jones. 2015. Recovery of Salmonella enterica serovar Enteritidis from hens initially infected with serovar Kentucky. *Food Chem.* 189:86-92. doi: 10.1016/j.foodchem.2015.02.018. Epub@2015 Feb 14.:86-92.
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 8. Type: Journal Articles Status: Published Year Published: 2015 Citation: Mellor, G. E., N. Fegan, K. S. Gobius, H. V. Smith, A. V. Jennison, B. A. D'Astek, M. Rivas, S. Shringi, K. N. Baker, and T. E. Besser. 2015. Geographically distinct Escherichia coli O157 isolates differ by lineage, Shiga toxin genotype, and total shiga toxin production. *J Clin. Microbiol.* 53(2):579-586.
 9. Type: Journal Articles Status: Published Year Published: 2015 Citation: Omulo, S., S. M. Thumbi, M. K. Njenga, and D. R. Call. 2015a. A review of 40 years of enteric antimicrobial resistance research in Eastern Africa: what can be done better? *Antimicrob. Resist. Infect Control.* 4:1. doi: 10.1186/s13756-014-0041-4. eCollection@2015.:1-0041.
 10. Type: Journal Articles Status: Published Year Published: 2015 Citation: Sheng, H., S. Shringi, K. N. Baker, S. A. Minnich, C. J. Hovde, and T. E. Besser. 2015. Standardized Escherichia coli O157:H7 Exposure Studies in Cattle Provide Evidence that Bovine Factors Do Not Drive Increased Summertime Colonization. *Appl. Environ. Microbiol.* 82(3):964-971.
 11. Type: Journal Articles Status: Published Year Published: 2015 Citation: Spencer, S. E., T. E. Besser, R. N. Cobbold, and N. P. French. 2015a. 'Super' or just 'above average'? Supershedders and the transmission of Escherichia coli O157:H7 among feedlot cattle. *J R. Soc. Interface.* 12(110):0446.
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 13. Type: Journal Articles Status: Published Year Published: 2015 Citation: Zhao, Z., L. J. Eberhart, L. H. Orfe, S. Y. Lu, T. E. Besser, and D. R. Call. 2015. Genome-Wide Screening Identifies Six Genes That Are Associated with Susceptibility to Escherichia coli Microcin PDI. *Appl. Environ. Microbiol.* 81(20):6953-6963.
 14. Type: Websites Status: Other Year Published: 2015 Citation: <http://vetextension.wsu.edu/research-projects/mart/>
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