2007

A review of Shiga toxin Escherichia coli and Salmonella enterica in cattle and free-ranging birds: potential association and epidemiological links

Kerri Pedersen
U.S. Department of Agriculture

Larry Clark
U.S. Department of Agriculture

Follow this and additional works at: http://digitalcommons.unl.edu/hwi
Part of the Environmental Health and Protection Commons

http://digitalcommons.unl.edu/hwi/129

This Article is brought to you for free and open access by the Wildlife Damage Management, Internet Center for at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in Human-Wildlife Interactions by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.
A review of Shiga toxin *Escherichia coli* and *Salmonella enterica* in cattle and free-ranging birds: potential association and epidemiological links


**Larry Clark**, U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center, 4101 LaPorte Avenue, Fort Collins, CO 80521-2154, USA

**Abstract:** Cattle are the main reservoir for human infection by pathogenic *Escherichia coli* and *Salmonella enterica*. To prevent entry of these foodborne pathogens into the human food chain, management factors at the farm level must be identified and controlled. External sources of contamination, such as birds, should be considered as potential sources of transmission over long distances. In this review, we focus on the epidemiology of infection by *E. coli* and *S. enterica* and the consequences of birds acting as disseminators of these pathogens at dairy farms in terms of cattle health and the subsequent effects on human health.

**Key words:** birds, cattle, *Escherichia coli*, prevalence, *Salmonella enterica*, salmonellosis, STEC

The STEC group of *E. coli* produces toxins similar to those produced by *Shigella dysenteriae* (Wray and Woodward 1997). STEC, sometimes referred to as verocytotoxin-producing *E. coli* (VTEC), are capable of causing hemorrhagic colitis (inflammation of the colon resulting in bloody diarrhea), hemolytic uremic syndrome (bloody diarrhea followed by renal failure), hemolytic anemia (fragmented red blood cells), and thrombotic thrombocytopenic purpura (a blood disorder characterized by low platelets, low red blood cell count, abnormalities in kidney and neurological functions (Lewis 1997, Saunders et al. 1999, Donnenberg and Nataro 2000, Murinda et al. 2002) in humans. STEC also have been identified as the causative agents of diarrhea and disease in other animals including cattle, pigs, sheep, goats, cats, and dogs (Willshaw et al. 1997, Wray and Woodward 1997, Zschöck et al. 2000).

The epidemiology of outbreaks of STEC in humans is linked to the consumption of contaminated bovine products (Griffin 1995, Zhao et al. 1995, Mcheie et al. 1997, Wray et al. 2000). Dairy cattle have been identified as the main reservoir of STEC (Wells et al. 1991, Faith et al. 1996, Shere et al. 1998, Schmidt et al. 2000). As a result, research has been dedicated to understanding infection in cattle and identifying management factors that can be modified to minimize the occurrence of STEC in the herd. Efforts also have been directed...
toward preventing infection in calves because their immature immune systems cause greater morbidity and mortality from STEC infection than in adults (Frank and Kaneene 1993).

The genus Salmonella consists of more than 2,600 serotypes that cause a wide spectrum of illness in humans (García-Del Portillo 2000). Most serotypes are not host-specific, although some serotypes are associated more commonly with infection in humans (S. typhi, S. paratyphi, Table 1), sheep (S. abortivovis), and poultry (S. gallinarum) (Varnam 1991, Daniels et al. 1993, Bell and Kyriakides 2002).

S. enterica have been identified as the causative agent of disease in many animals including sheep, cattle, pigs, reptiles, and various bird species (Girdwood et al. 1985, Gay and Hunsaker 1993, Hudson et al. 2000, Winfield and Groisman 2003). Because cattle represent a major reservoir for human foodborne infection (Wells et al. 2001), research efforts have been directed towards reducing S. enterica in the herd to prevent contamination at the slaughterhouse and subsequent entry into the human food chain. Prevention of salmonellosis in cattle is a critical factor for dairy producers to reduce economic losses incurred from culling, reduced feed efficiency, decreased weight gain, decreased milk production, abortion, and mortality (Huston et al. 2002).

Sources of infection

**Table 1.** The top 10 most frequently reported Salmonella serotypes from cattle and humans in Colorado reported to Centers for Disease Control (CDC) in 2003 (2004).

<table>
<thead>
<tr>
<th>Human</th>
<th>Cattle</th>
</tr>
</thead>
<tbody>
<tr>
<td>S. typhimurium</td>
<td>S. newport</td>
</tr>
<tr>
<td>S. enteritidis</td>
<td>S. typhimurium var. 5-</td>
</tr>
<tr>
<td>S. newport</td>
<td>S. typhimurium</td>
</tr>
<tr>
<td>S. heidelberg</td>
<td>S. montevideo</td>
</tr>
<tr>
<td>S. javiana</td>
<td>S. agona</td>
</tr>
<tr>
<td>S. montevideo</td>
<td>S. dublin</td>
</tr>
<tr>
<td>S. saintpaul</td>
<td>S. kentucky</td>
</tr>
<tr>
<td>S. muenchen</td>
<td>S. muenster</td>
</tr>
<tr>
<td>S. oranienburg</td>
<td>S. uganda</td>
</tr>
<tr>
<td>S. infantis</td>
<td>S. anatum</td>
</tr>
</tbody>
</table>

Human health risks associated with dairy cattle

Fecal shedding of E. coli O157 occurs in the most cattle herds, with an increase in prevalence occurring during summer months when environmental conditions such as temperature and moisture are conducive to growth of E. coli (Herriott et al. 1998, Van Donkersgoed et al. 1999). Shedding of S. enterica is common in cattle during late summer and early fall (McEvoy et al. 2003). Infected animals often appear asymptomatic and shed STEC and S. enterica intermittently, making detection and diagnosis based on clinical signs more difficult (Kabagambe et al. 2000, Sargeant et al. 2000, Wray and Davies 2000, Yilmaz et al. 2002). Limiting shedding in cattle is essential to prevent dissemination of the bacteria throughout the herd and to reduce the risk of carcass contamination with infected fecal matter at the slaughterhouse, and subsequent entry of STEC or S. enterica into the human food chain.

Cattle were identified as the primary reservoir of E. coli strain O157:H7 (Montenegro et al. 1990, Cobbold and Desmarchelier 2000, Kobayashi et al. 2001, Yilmaz et al. 2002), soon after it was first recognized in 1982 as an important disease-causing pathogen in humans (Zhao et al. 1995, Faith et al. 1996, Troutt and Osburn 1997). Initially, E. coli O157 was thought to be the only serogroup of E. coli important in human disease, but since then many non-O157 STEC pathogenic strains of E. coli have been identified (Griffin 1995, Beutin et al. 1998, Appendix). Cattle are also major reservoirs of S.
enterica (Wells et al. 2001), but unlike E. coli, all strains of S. enterica are potentially pathogenic to humans (Lewis 1997, McEvoy et al. 2003).

Most dairy cattle enter the meat market when milk production declines, reproduction fails, or mastitis, disease or injury becomes debilitating (Troutt and Osburn 1997). According to the USDA's National Animal Health Monitoring System 1996 Dairy Study, 30.9% of cull (market) dairy cattle were shedding verotoxigenic E. coli O157, and 66.7% were shedding Salmonella (Wells et al. 1998a). Transportation, modified food rations, and poor health are stressors that induce S. enterica and STEC shedding (Daniels et al. 1993, Fedorka-Cray et al. 1998, Galland et al. 2001), and consequently create additional opportunities for contamination of carcasses with enteric bacteria or interchange of bacteria between carcasses (Bettelheim 1997). Contamination at the slaughterhouse increases the risk that the consumer will eat tainted meat, especially if it is undercooked. Limiting contamination is desirable because approximately 17% of the nation’s ground beef supply is produced from culled dairy cattle (Troutt and Osburn 1997, Wells et al. 1998b), and the infectious dose of STEC for humans is as low as 10 bacteria (Fukushima et al. 1999).

Various modes of indirect transmission pose a threat to cattle health. For example, manure slurry often is applied as fertilizer to agricultural crops and pastures used for grazing (Mechie et al. 1997). Due to the long-term survival of STEC and S. enterica in feces (Pell 1997, Fukushima et al. 1999, Huston et al. 2002), cattle may become infected indirectly by STEC or S. enterica while grazing on pastures fertilized with contaminated slurry or by eating silage or other feed harvested from fields treated with slurry (Mechie et al. 1997, Himathongkham et al. 1999). The length of time that STEC and S. enterica are able to survive in the environment depends on the manure’s source, pH, dry matter content, age and chemical composition (Pell 1997). E. coli can survive in the environment anywhere from 1 (Winfield and Groisman 2003) to 105 days (Himathongkham et al. 1999), whereas S. enterica can survive up to a year in soil (Winfield and Groisman 2003). In a prevalence survey of 60 dairy cattle herds, a tentative association was found between the number of days between application of manure and grazing or hay harvesting and E. coli O157:H7 status in the herd (Hancock et al. 1994). The survey revealed that the longer slurry-treated fields are left before grazing or harvesting, the lower the risk that cattle will become infected. Contaminated manure slurry used as fertilizer also poses a threat to other animals that graze on crops while STEC or S. enterica are still viable. Proper management of manure slurry and an understanding of the factors affecting survival of STEC and S. enterica in slurry are essential to prevent exposure.

Another indirect mode of transmission at dairy farms is through cattle drinking water. S. enterica has been isolated frequently from water sources, which may serve as bacterial reservoirs (Winfield and Groisman 2003). E. coli was demonstrated to persist in cattle drinking water several days after initial contamination (Rice and Johnson 2000). The ability of the bacteria to survive in water not only presents an opportunity for cattle to become infected, but birds or other animals that use water troughs also may become infected and spread pathogens within the farm or to neighboring farms (Figure 1).

**Free-ranging birds as sources of infection in cattle**

Many management factors such as herd size, grouping, manure management, equipment sanitation, feed composition, and feed additives have been associated with STEC and S. enterica prevalence in cattle herds (Bender 1995, Van Donkersgoed et al. 1999). Unfortunately, little attention has been given to external sources of contamination such as veterinarians, introduction of new cattle into the herd, wildlife, rendering trucks, feed, etc. (Figure 1). Although rats and mice may prolong persistence of these microorganisms on the farm by acquiring

![Figure 1. Potential modes of transmission of Escherichia coli and Salmonella enterica. Dotted lines represent indirect transmission. Cattle manure or bird feces are direct methods of contamination that could lead to infection in birds and cattle. Transmission to humans occurs after consuming contaminated meat, unpasteurized milk, or other dairy products.](attachment:image-url)
Pigeons and cattle. STEC have been detected in various tissues collected from nestlings of house sparrows (*Passer domesticus*) and tree sparrows (*P. montanus*) (Pawiak et al. 1991). Other bacterial species including *Salmonella* spp., *Campylobacter jejuni*, and *Clostridium perfringens* have been identified in fecal samples of house sparrows collected near broiler chicken houses, suggesting that birds gaining access to livestock facilities may transmit bacteria (Craven et al. 2000). The potential for transmission is important because house sparrows, like pigeons, often are found year-round at livestock facilities (Kirk et al. 2002).

Infections with the bacteria *E. coli* O86:K61 and *Salmonella typhimurium* DT40 were identified as the most common causes of mortality in various species of free-ranging finches of the family Fringillidae in Britain (Foster et al. 1998, Pennycook et al. 1998). The *eae* gene and cytolethal distending toxin production were detected in the strains of *E. coli* O86 isolated from the finches, indicating the potential of the organism to cause disease and mortality in the finches. *E. coli* O86:K61 also has been associated with disease in humans, cattle, and other animals (Foster et al. 1998). Given their propensity to congregate in large numbers at birds feeders, finches may pose a threat to other birds and humans that come in contact with fecal-contaminated bird feeders. Although the free-ranging finches examined in Britain were submitted from households that provided supplementary food (Pennycook et al. 1998), house finches are commonly observed at dairies (Kirk et al. 2002). Consequently, infected finch populations have the potential to disseminate these pathogens to domesticated livestock.

Outbreaks of salmonellosis attributed to serotype *S. typhimurium* in bird populations have been responsible for large-scale mortality
in many species of domestic and free-ranging birds (Faddoul and Fellows 1966, Goodchild and Tucker 1968, Grimes 1979, Hudson et al. 2000, Daniels et al. 2003). Salmonella enterica also have been identified in asymptomatic birds (Adesiyun et al. 1998, Kirk et al. 2002). S. enterica infection often spreads via backyard bird feeders where high densities of free-ranging birds congregate during winter when food is scarce (Pennycook et al. 2002). Free-ranging birds such as European starlings (Sturnus vulgaris), great-tailed grackles (Quiscalus mexicanus), common grackles (Quiscalus quiscula), and brown-headed cowbirds (Molothrus ater) (Clark and McLean 2003) flock to dairy farms (as many as 5,000 to 10,000 birds on some dairies) during fall and winter (Kirk et al. 2002). This high concentration of birds increases the risk of transmission of S. enterica to other birds and cattle, especially in feed bunk. Free-ranging birds have been implicated in contamination of livestock feed while it is stored at the farm (Daniels et al. 2003) and immediately after the feed is placed into feed bunk (Smith and House 1992). The risk that cattle will become infected is magnified by the presence of free-ranging birds, which may transport S. enterica to the farm from outside sources or recirculate the microbe within the farm to uninfect ed animals. S. enterica survive in the environment for extended periods, increasing the likelihood for birds to come into contact with the bacteria (Čížek et al. 1994) and subsequently infect other animals. Serotypes of S. enterica commonly associated with infection in humans and animals have been identified in asymptomatic free-ranging birds, suggesting that transmission across species is possible (Sambyal and Sharma 1972).

Even though pigeons and other birds have been clearly identified as important carriers of STEC and S. enterica, little is known about the length of time that STEC or S. enterica are shed or remain viable in bird droppings. Pigeons infected experimentally with E. coli O157 shed the pathogen for up to 29 days depending on the infective dose (Čížek et al. 2000). Research suggests that E. coli coliform counts in Canada goose (Branta canadensis) droppings increase upon excretion (Feare et al. 1999). If this is true also for pigeons and other birds that live in close association with cattle, the risk of indirect transmission would increase.

Migratory birds are important contributors to losses attributed to consumption of feed. However, peridomestic birds, such as pigeons and house sparrows, may be more culpable of disease transmission. Migratory birds are generally absent from dairies during the summer when a seasonal fluctuation in prevalence of STEC is observed in cattle (Herriott et al. 1998, Garber et al. 1999, Van Donkersgoed et al. 1999). In contrast, peridomestic birds are present during this time and often loaf and roost in or near cattle barns, thus increasing the potential for disease transmission.

Another concern is that indirect transmission will occur when birds or cattle forage or consume silage or feed grown on slurry-treated fields contaminated with STEC or S. enterica. Once infected, birds may redistribute STEC or S. enterica within the farm or disseminate STEC or S. enterica to previously uninfected farms. Cattle may also facilitate the cycle by transmitting bacteria to other cattle or birds after becoming infected from contaminated feed sources. In general, farmers do not implement rigorous bird control methods because the economic loss associated with bird consumption of cattle feed is perceived to be less than the intensive labor and financial expenditures associated with an effective bird control program. This perception may change, however, because the additive effects of feed loss and bacterial transmission as a precursor to disease may be sufficient evidence to justify a bird control program.

**Conclusions**

Because STEC and S. enterica are able to survive adverse environmental conditions (Pell 1997, Winfield and Groisman 2003), the bacteria have many opportunities to infect new hosts and continue the cycle via indirect transmission. Indirect transmission of STEC or S. enterica to cattle or birds may occur through contaminated domestic animals or wildlife that defecate in drinking water or food sources that are later ingested by other animals (Figure 1). Crops fertilized with contaminated manure slurry may pose a threat if conditions are conducive to bacterial growth (Himathongkham et al. 1999). These crops then present a source of infection for birds such as gulls or Canada geese, that forage on farmland or to cattle that are fed harvested grains or silage that has been grown and stored in conditions that support bacterial growth. In addition, contaminated manure slurry, if not managed properly, may seep into ground water and pose a threat to human health.

Migratory birds, such as European starlings, common grackles, and red-winged blackbirds (Agelaius phoeniceus) are found in large numbers at dairies during the fall and winter and may amplify transmission of diseases by spreading the bacteria from 1 farm to another. Peridomestic birds, such as pigeons and sparrows, may
be more important in recirculation of STEC within the farm. Once birds are infected, the risk of cross contamination between cattle and peridomestic birds increases because of their close association.

Birds may be more susceptible than cattle to indirect contamination because of their mobility. Nonetheless, cattle are vulnerable to infection through various outside sources. Many external sources of contamination may influence prevalence of STEC and S. enterica in cattle and birds (Figure 1).

Knowledge is paramount in understanding the epidemiological links between STEC and S. enterica infection in cattle and free-ranging birds and successful management of both dairy herds and bird populations to minimize cross-infections. Ultimately, the producer loses money if free-ranging birds play a role in disseminating and redistributing STEC or S. enterica. The benefit to exploring all potential modes of transmission and cross-contamination lies not only in adapting management efforts to minimize economic loss to the producer, but more importantly, in preventing entry of STEC and S. enterica into the human food chain. Epidemiological knowledge is necessary to make educated management decisions that will minimize bacterial prevalence in dairy herds and protect human health via safer bovine products.

**Literature cited**


### Appendix

STEC serogroups identified in wild birds, cattle, and humans.

<table>
<thead>
<tr>
<th>STEC</th>
<th>Birds</th>
<th>Cattle</th>
<th>Humans</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>O1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Sussman 1997, Bopp et al. 2003, Pedersen 2004</td>
</tr>
<tr>
<td>O79</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Bopp et al. 2003</td>
</tr>
</tbody>
</table>
Kerri Pedersen is a wildlife disease biologist with the U.S. Department of Agriculture, National Wildlife Research Center. Her previous employment was with the Southeastern Cooperative Wildlife Disease Study. She received her B.S. degree in biology from Oregon State University and her M.S. in ecology from Colorado State University.